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The purpose of the REVIEW is to report the major research findings during a designated period, organized by areas of interest. The REVIEW identifies the significant studies, summarizes them, and, within limitations of space, critically analyzes them. It seeks to present syntheses of research findings which reflect educational insight and stimulate new research.

The more active fields of educational research are reviewed every three years; the less active fields are included in alternate cycles. (See inside back cover.)

Each issue is organized by a committee of AERA members, specialists in the issue's topic, who work under the leadership of a chairman chosen by the editor with the advice of the Editorial Board. The chairman develops the plan for the issue with the advice of his committee and the editor, and, with their aid, invites specialists to contribute chapters. Contributors are chosen for their particular competency.

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The Methodology of Educational Research

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TABLE OF CONTENTS

This issue of the REVIEW was prepared by the Committee on Methodology of Educational Research

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FOREWORD

This issue of the REVIEW, like corresponding preceding issues, presents a cross section of research methodologies used during the last triennium. The topic, sampling, is omitted because it is being covered by the report of the Second Annual Phi Delta Kappa Symposium, which is shortly to appear. Chapters in it by Leslie Kish and F. G. Cornell cover sampling from an elementary level to more complex ones. Discussion of instrumentation is added in this issue because educational research has reached a stage of development where pencil-paper data-collection techniques are no longer sufficient.

The importance of instruments in the physical sciences was indicated by Klopsteg (1960). Among the 138 Nobel laureates from 1901 to 1960, recognition was accorded to 112 for research in which instrumentation was a vital means. Both American Nobel prize winners in 1960 were recognized because of their contributions to instrumentation.

Some educational phenomena are inaccessible to direct observation, and others occur so rapidly or so frequently that a human observer is overwhelmed. As a result of recent advances in instrumentation, it is now feasible to record certain aspects of human behavior—particularly those related to stress and motivation—in a manner that is more objective than pencil-paper techniques. Interest in mechanical instructional and testing devices has been revived. For educational researchers such devices appear to be particularly helpful in providing a means of rigorous control in studies of instruction and learning. Virtually all applications of instrumentation in educational research have been in studies of instruction and learning by means of mechanical devices; the chapter devoted largely to teaching machines is especially apropos.

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CHAPTER I

The Role of Research in Education—Present and Future

NICHOLAS A. FATTU

THIS CHAPTER is devoted to consideration of materials relevant to educational research methodology, but not treated in the chapters as they are constituted. The discussion is framed broadly in terms of two questions: What is the role of research in education? and What is a desirable role for educational research in the future? The first describes some issues relative to educational research. The second discusses recent developments in the social sciences that have not been, but might profitably be, explored in educational research: model building, simulation techniques, systems analysis, mechanized learning and thinking models, information theory, and decision theory.

The Role of Research in Education

Studies of the role of research in education were concerned with discussions of professional status and professional responsibility: Brown (1960); Harris (1960); Flagle, Huggins, and Roy (1960); Goode (1958); Hunt (1956); Kidd (1959); and the first Phi Delta Kappa symposium (Banghart, 1960).

It was said that research provides the foundation of professional status. Brown (1960) summarized the requirement of a profession for practitioners (a) who are free and responsible individuals and who can be depended on because of their professional integrity to establish and maintain their professional standards of performance; (b) who keep a learning approach throughout life as a means of fulfilling their professional responsibilities through ready application of new knowledge.

Harris (1960) urged a "coming of age" in education. Technological schools, he contended, by abandoning the trades-training approach and instituting abstract theoretical approaches, now design engineering curriculums to make extensive use of intellectual formulations and research. According to Harris, technology, by coping intellectually with the problems it faced, won increasing respect and stature, but education appears to be still largely an application of psychological rules of thumb. Harris asserted that, to "grow up," education must conceptualize its processes and develop a series of new intellectual formulations. Improved conceptualization was also urged by the American Council on Education (ACE) (1939); the American Educational Research Association (AERA) (1956); Brim (1958); Brown (1960); Coladarci (1960); Goethals (1958); McConnell,

Scates, and Freeman (1942); Travers (1958); Traxler (1954); and Ulich (1937).

Flagle, Huggins, and Roy (1960) maintained that the professions have been forced to give research a larger role by the rapidly changing character of the world. For example, coal can be mined, iron can be smelted and refined, easily located petroleum can be exploited without scientific aid; but it is estimated that within a generation 75 percent of electrical energy must come from nuclear or solar sources. With unprecedented population increase, underdeveloped nations demand their full share of the world's goods. Inevitably all phases of civilization must become more complex and technical and demand greater scientific sophistication. Technology has become intellectual and strongly oriented toward research because the demands of the world have forced it to.

Not only have science and technology become more complex, but the rate at which changes occur has led to further problems. Johnson (1960b) estimated that knowledge of the physical sciences doubles every 15 years, and of the social and management sciences every 50 years. The latter increases at about the same rate as the population of the world. General Electric has indicated that over 40 percent of the products it currently sells were not in existence 10 years ago (Suits, 1958).

Brim (1958), Becker (1960), Hunt (1956), Kidd (1959), Traxler (1954) saw educational research as not keeping pace with the world. Becker (1960), finding an investment in American education of 24 billion dollars during 1960, observed serious deficiencies at all levels, and he believed that educational resources must be used more efficiently. His opinions were shared by Keezer (1960a) and by the National Bureau of Economic Research report on the economics of education. Economics of research and education was also explored by Keezer (1960a, b), Schultz (1959), Shockley (1957), and Siegel (1960). The point emphasized was that continuing expenditure on education presupposes a continual flow of good ideas. Simons (1960) saw the lack of such ideas as crucial and indicative of a necessity for greater emphasis on basic research.

The opinion that educational research has not kept pace with the world was widely expressed. Brim (1958) reported on deficiencies in educational research and proposed work to be performed by social scientists. Several professional organizations have expressed their concern in various ways. The Organization for Research in Education was established by the National Academy of Sciences and the National Research Council. (It was dissolved when the Council for Research in Education was established.) According to the first Phi Delta Kappa symposium (Banghart, 1960), more educational researchers are employed by foundations, industrial organizations, and agencies of the federal government than by public schools and universities.

Some notable activities were directed toward increasing educational research: the Council on Educational Research was established through the efforts of the late Percival M. Symonds and his associates at AERA.

The Phi Delta Kappa Annual Symposium on Educational Research and the Big Ten Research Directors Conferences were instituted. The Center for Advanced Study in the Behavioral Sciences has begun to consider educational researchers.

The most important boost for educational research was the establishment of the Cooperative Research Program of the U.S. Office of Education and the various titles within the National Defense Education Act. When the history of educational research is reviewed with the perspective of the future, these federal programs will probably stand out as the significant turning points in educational research.

Unfortunately these efforts are still too little and too late. A recent survey reported at the first Phi Delta Kappa symposium (Fattu, 1960) indicated that, of the 94 colleges and universities which grant the doctorate in education, only 10 could be said to be making a serious effort to encourage educational research by maintaining a favorable intellectual climate and giving adequate financial support, by making time and facilities available for faculty research, or by giving significant consideration to research when appointing new faculty members. It was suggested that the observed indifference to research might be related in part to the domination of these institutions by practitioners who attained their positions of influence through literary and forensic skills rather than through contributions to and understanding of science. In terms of allocation of resources—finances and faculty time—all of the 10 most highly respected institutions devoted more to research than to field services; among the rest the emphasis was reversed. Similar findings were reported by Phillips (1957) and Ryans (1957).

To summarize, more research is needed if education is to carry out its responsibilities in a rapidly changing world. More funds and other support are necessary to educational research.

Although American public education is more efficient than at any earlier time (it is probably the most efficient in the world), it is not as effective as it can and must be to maintain the American way of life. There are many competent, dedicated educational researchers, but their number does not meet the demand. Current trends in industry and government suggest that other agencies are prepared to assume responsibility for adding new knowledge. The implications of such an outcome for education as a profession should be a matter of concern to all educators.

The Nature of Educational Research

Educational research seemed to have fluid boundaries encompassing virtually all phases of scholarly activity associated with the educative process and organization. It included carefully designed experimental studies of current and proposed practices; mass collections of data, such as surveys, not illumined by systematic conceptual guiding lines, thought of

as routine work; theoretical, historical, philosophical, and integrative scholarly activities; critical reviews of research literature and summaries of issues and problems; applied research focused on local practices and policies, planned to stimulate interest in more fundamental studies, as well as to develop the school staff or solve an immediate problem.

The first Phi Delta Kappa symposium (Banghart, 1960) defined educational research variously as ranging from routine clerical operations to sophisticated disciplined inquiry. Descriptions of educational research included a variety of activities: listings and tabulation by titles (Blackwell, 1958; Brehaut, 1958); surveys of activities of researchers or organizations (Phillips, 1957; Ryans, 1957; H. K. Miller, 1958; MacArthur, 1958; Weitz, 1957); discussions of the nature of educational research (American Council on Education, 1939; AERA, 1956; Coladarci, 1960; McConnell, Scates, and Freeman, 1942; Levin, 1956; Travers, 1958; Traxler, 1954; Ulich, 1937; Walker, 1956); discussions of a framework for educational research (Goethals, 1958; Tiedeman and Cogan, 1958); discussions of activities of scientists (Schwab, 1960; Simons, 1960; Helmer and Rescher, 1959).

A consideration related to the definition of educational research is implied by the question, Is there a legitimate area for educational research? Discussion of the question appeared in several forms, but may be summarized as follows: Education is a practice and an art. The basic findings come from psychology, sociology, and other social sciences. Education takes these findings and applies them.

It is difficult to reconcile such a position with that observed among groups which currently make the most use of research—government, industry, and medicine. These fields recognize that discovery of new knowledge is only one step in the process toward effective utilization. For example, knowledge required to produce nuclear fission existed before the Manhattan project; it took a great deal of applied research and development to translate it into products and processes. In fact, the recent studies of the research and development process by the Carnegie Institute of Technology indicate that it is twice as costly (in time and resources) to produce the product or process as it was to make the original discovery.

A second relevant question is, What standards of research performance are self-imposed or enforced by the group? Again direct recent consideration is scarce. Lerner's (1959) and Weiss's (1960) comments more directly suggest that standards of expectation might be more explicitly defined and enforced. About a quarter of a century ago more direct attention seems to have been given to this matter (McConnell, Scates, and Freeman, 1942; ACE, 1939).

Desirable Amount of Research

No studies were discovered in the field of education that gave direct attention to the question of how much research is desirable. The National

Science Foundation awarded grants to the Carnegie Institute of Technology and the Western Reserve University to study this problem in the physical sciences.

Discussions of this topic found in business publications were relatively frequent, probably because survival in a rapidly changing competitive environment demands innovation. The rule of thumb was, Don't do any less than your nearest competitor.

Becker (1960) commented on the effects of underinvestment in education. Noting that public and private expenditures for education run to many, many billions of dollars each year, he pointed out that all types of education offer a fertile ground for comparative productivity and input-output studies.

The Distribution of Research Activity

Research activities are classified by the National Science Foundation as "basic research," "applied research," and "development."

Basic research includes original investigation for the advancement of scientific knowledge. The primary aim of the investigator is achievement of fuller knowledge or understanding of the subject matter under study, rather than making practical applications of new knowledge. Applied research is directed toward practical applications of scientific knowledge. Development is the systematic use of scientific knowledge for the production of useful materials, devices, systems, methods, or processes, exclusive of design and production engineering (Fattu, 1960). It is evident that the sequence from research to action is in that order. An invention of a device, procedure, or method cannot be made until the key, or last essential, fact is discovered: for example, a television set could not be produced until all the basic discoveries of electromagnetic radiation and synchronization of transmitted impulses had been made.

Tyler, in the Phi Delta Kappa symposium (Banghart, 1960), illustrated the utility of basic research using research in connection with hybrid corn as an example. Applied research on corn and cultivation practices had brought relatively small increments in yield; the development of hybrid corn, however, produced greatly increased yield. Here the breakthrough resulted from knowledge of plant genetics rather than from cultivation practices. The original discovery was made in 1908, but applications were not made until the 1930's when economic pressures forced the development. Also, hybrids must be developed or adapted to fit conditions of a region. Griliches (1957) summarized the story in detail and cited many related references. The example should be instructive to one who wishes to trace the interaction of basic research, applied research, and development.

Colleges and universities claim to add to as well as to disseminate knowledge; hence it would seem that basic research should find a congenial atmosphere within the university. The National Science Founda-

tion reported that, in engineering schools, 57 percent of total expenditures budgeted for research and development was devoted to basic research. In industry, funds for basic research totaled 344 million dollars, or about 4 percent of the 9.4 billion dollars spent for research and development. Corresponding data for educational research are not available and would be meaningless at the present time. Certainly, educational research requires more applied research and development than basic research, but the funds available for all educational research are so much less than those available in other areas that the task would seem to be first raising the amount, before considering the distribution.

Selection and Preparation of Educational Research Workers

Comments on training for research were presented by the American Psychological Association (APA) (1959), Brim (1958), Brown (1960), Cronbach (1957), Goode (1958), Harris (1960), Keezer (1960b), Kidd (1959), Travers (1958), and Walker (1957).

Selection of research workers was differentiated from that of practitioners. According to Cronbach (1957), Taylor (1956, 1958, 1959), and Thistlethwaite (1959), selection of researchers should emphasize creativity, as well as measures of aptitude, school performance, and motivation toward original inquiry.

It was suggested that a high grade in undergraduate work might be evidence of conformity that might be undesirable in research. Undergraduate performance in tasks requiring creativity, originality, and intellectual nonconformity were thought of as probably being better predictors. Motivation toward research was also considered a prime criterion for selection. Perseverance seemed a significant factor in scientific achievement. (In his autobiography, Max Planck stated that for 19 years the exploration of the Second Law of Thermodynamics occupied every waking moment that he could recall. Kepler and Galileo worked more than 30 years before they produced their formulations. Breakthroughs in science apparently require a high order of creativity and a concentrated effort sustained over a period of many years.) It seems reasonable to believe that the more complex the area of investigation, the more sustained effort is required.

There was agreement that the training of researchers should also differ from that of practitioners. It was suggested by several authors, including Helmer and Rescher (1959), that researchers need to understand the strategy and tactics of science and the language of science (including modern mathematics) and an academic scientific area. The preparation of research workers in the physical sciences appears to be more demanding than that for social scientists.

Agreement was almost unanimous that the best preparation for research is apprenticeship to a skilled researcher. The opportunity to participate in and carry on independent research and publication was regarded as

indispensable. The APA report (1959) summarized this point of view as follows: "Everything we have found points to the fact that course work, formal examination requirements, and anything else that could be standardized concerns what is ancillary to research training. What is of the essence is getting the student into a research environment and having him do research with the criticism, advice, and encouragement of others who suffer the same pain and enjoy the same rewards. . . . Research is learned by doing and taught mainly by contagion. Research must first be going on if there is to be research training. What formal courses are offered is no index of quality of a department as regards such training; the only adequate index is the eventual productivity of the individuals that the department produces."

The first topic discussed here has been some issues relative to educational research. No definitive answers were found, and at this time it would be premature to offer any. However, the well-being of education as a profession may lie in serious consideration of these and related topics.

Some Recent Developments in Educational Research

This section is a brief discussion of recent developments—operations research and systems analysis—that have been used profitably in a social science. Perhaps these methods can be explored, applied, and revised to help solve certain problems in education.

Operations research is the application of mathematical and other scientific procedures and common-sense procedures to the solution of problems encountered within an organization—specifically to co-ordinate the operations of the various functional units to attain the over-all objectives of the organization. Operations research may be defined as the application of scientific methods, techniques, and tools to problems involving operations of enterprises in order to provide optimal solutions.

Kershaw and McKean (1959) discussed the potential for operations research in relation to education in general terms. A comprehensive summary was made by Dorfman (1960). (In reading Dorfman, one should bear in mind that to master the mathematics is not to qualify as an operations researcher; one learns to plan and carry out operational experiments by experience.) A general view can be had from Johnson (1960a) in conjunction with Dorfman; then Flagle, Huggins, and Roy (1960) and Machol (1960). A student who wishes to study the matter thoroughly should consult the extensive bibliographies of the Case Institute of Technology Operations Research Group (1958) and Shubik (1960).

Some topics of operations research potentially useful for the study of educational problems are mathematical model building, mechanized models of the learning and thinking processes, and simulation procedures. A model is thought of as an analogue. It reproduces those features

of the thing modeled that are significant for the purpose at hand. In some cases, significant features are directly observable—as with maps, geological or topological representations, buildings, and the like. Models may incorporate features which show how the thing modeled responds to forces acting on it—models of ships, airplanes, electric generating systems, or atoms.

Orcutt (1960) saw a model as a physical representation, a prose description, an example of pictorial geometry, a mathematical statement, or a computer program presentation. Some concepts can be described and worked more easily in the language of one discipline than in that of another. In physical science, the optimal description appears to have been achieved in rigorous mathematical models. Mathematical models are preferred because of their precision in representing the pertinent data and because of the accuracy of their substantive interpretation. Mathematical models represent the basic structure of physical science. It was claimed that in the social sciences models have been brought to a stage where objective scientific method can be applied to them; both Cronbach (1957) and Thomson (1960) stated that mathematical formulation constitutes an aspect of science.

Machol (1960) stated that "it is possible to describe analytically any human function which can be reasonably defined in objective terms," and he included thinking insofar as the term is definable. Arrow, Karlin, and Suppes (1960) edited a symposium on mathematical models in economics, management science, and psychology. Bush and Estes (1959) presented similar models of various learning functions.

For those unfamiliar with the field, a suggested order of reading, starting with verbal description, follows: Lachman (1960) for general discussion of models in theory construction; Latil (1957) for cybernetics; Cyert, Feigenbaum, and March (1959) for a comprehensive review of management applications; Miller, Galanter, and Pribram (1960) for a discussion of "Totes." Mathematical background can be had from Cogan (1959) and Karlin (1959). Without the mathematics, these methods cannot be used. Perhaps a team approach might make problems more tractable for educational researchers.

Mechanized or programed models of learning and thinking processes were discussed at the verbal level by Friedberg (1958), Friedberg, Dunham, and North (1959), Gelernter and Rochester (1958), and Hovland (1960). Rosenblatt (1958) described the perceptron or automaton for perceiving and recognizing geometric shapes. Reiss (1960) discussed a model of neuromuscular organisms, the most frequently discussed type of programed model. The advantage of mechanized models is that they are more easily understood than mathematical models, but they retain the feature of requiring explicit and unambiguous analysis of the operation. Preparation of programed models points out gaps in knowledge and also provides incentive and means for filling the gaps. Machol (1960) believed that enterprising students might develop a programed model

of the instructional cycle for a variety of subject matters and educational goals. Development of such a model would clarify what is meant by such terms as "method," "goals," and "teaching."

One of the most interesting operations-research methods is simulation. Conway, Johnson, and Maxwell (1959), Orcutt (1960), and Shubik (1960) provide a good introduction to the study. Simulation is the operation of a model or simulator. The model is amenable to manipulations which would be impracticable or too expensive to perform on the entity represented; training jet aircraft pilots on Link Trainers is an example. The model can be studied, and, from it, properties of the behavior of an actual system inferred—an aircraft model in a wind tunnel or the hydraulic model of an economic system.

The most interesting simulations are those done by an electronic computer. The machine is told in general terms how a certain phenomenon takes place and is programed to run through the appropriate events many times under varying circumstances and to give a summary of what happened. How this is done can be seen in the instance of traffic-flow planning. The way traffic lights are controlled in a large city is often haphazard. The mathematical problems in optimizing the setting of lights are beyond present human capabilities. No matter. Let the traffic commission's plan be programed on a computing machine, and let several thousand programed "cars" loose through the "city," and see how long it takes them on the average to reach their destinations. Then try other programs, and make adjustments until the flow of traffic is improved.

The method is not basically different from present-day planning, which is also based on trial and error, but what would take years to observe, in actuality, takes hours in simulation. It is not surprising that simulation is most frequently used in gaming designed to give decision makers, in a matter of hours, years of experience in such matters as developing production schedules and buying and selling stocks. In educational research, the study of players and the opportunity to test hypotheses about the behavior of individuals and/or decision systems is possible.

This introduction has attempted to point up some issues related to educational research and to suggest methods that have proved useful in the social sciences. For educational research to advance from a verbal description of educational phenomena to more precise formulations will necessitate that researchers have a basic knowledge of modern mathematics and computers; mastery of these fields, as well as statistics, will probably have to be required for the advanced degrees that certify competence in educational research.

Bibliography

AMERICAN COUNCIL ON EDUCATION. *Educational Research; Its Nature, Essential Conditions, and Controlling Concepts.* Studies, Series I, Vol. 3, No. 10. Washington, D.C.: the Council, 1939. 189 p.

AMERICAN EDUCATIONAL RESEARCH ASSOCIATION. "Twenty-Five Years of Educational Research." *Review of Educational Research* 26: 199-344; June 1956.

AMERICAN PSYCHOLOGICAL ASSOCIATION. "Report of the Seminar on 'Education for Research in Psychology,' July 28 to August 22, 1958." *American Psychologist* 14: 167-79; April 1959.

ARROW, KENNETH J.; KARLIN, SAMUEL; and SUPPES, PATRICK, editors. *Mathematical Methods in the Social Sciences.* Stanford, Calif.: Stanford University Press, 1959. 365 p.

BANGHART, FRANK W., editor. *First Annual Symposium on Educational Research.* Bloomington, Ind.: Phi Delta Kappa (Eighth Street and Union Avenue), 1960. 112 p.

BECKER, GARY S. "Underinvestment in College Education?" *American Economic Review* 50: 346-54; May 1960.

BLACKWELL, A. M. *Lists of Researchers in Education and Educational Psychology.* Supplement 3. London: National Foundation for Educational Research in England and Wales, 1958. 64 p.

BREHAUT, WILLARD. *A Quarter Century of Educational Research in Canada; An Analysis of Dissertations in Education Accepted by Canadian Universities, 1930-55.* Information Series No. 10, Department of Educational Research. Toronto: University of Toronto, College of Education, 1958. 283 p.

BRIM, ORVILLE G., JR. *Sociology and the Field of Education.* New York: Russell Sage Foundation, 1958. 93 p.

BROWN, J. DOUGLAS. "Education for a Learned Profession." *American Scientist* 48: 210A-16A; September 1960.

BUSH, ROBERT R., and ESTES, WILLIAM K., editors. *Studies in Mathematical Learning Theory.* Stanford Mathematical Studies in the Social Sciences, No. 3. Stanford, Calif.: Stanford University Press, 1959. 432 p.

CASE INSTITUTE OF TECHNOLOGY OPERATIONS RESEARCH GROUP. *A Comprehensive Bibliography on Operations Research, Through 1956, with Supplement for 1957.* New York: John Wiley & Sons, 1958. 188 p.

COGAN, E. J. *Modern Mathematical Methods and Models.* Ann Arbor, Mich.: Cishing-Malloy, 1959. 2 vol., unpaged.

COLADARCI, ARTHUR P. "Towards More Rigorous Educational Research." *Harvard Educational Review* 30: 3-11; Winter 1960.

CONWAY, R. W.; JOHNSON, B. M.; and MAXWELL, W. L. "Some Problems of Digital Systems Simulation." *Management Science* 6: 92-110; October 1959.

CRONBACH, LEE J. "The Two Disciplines of Scientific Psychology." *American Psychologist* 12: 671-84; November 1957.

CYERT, R. M.; FEIGENBAUM, E. A.; and MARCH, J. G. "Models in a Behavioral Theory of the Firm." *Behavioral Science* 4: 81-95; April 1959.

DORFMAN, ROBERT. "Operations Research." *American Economic Review* 50: 575-623; September 1960.

FATTU, NICHOLAS A. "A Survey of Educational Research at Selected Universities." *First Annual Symposium on Educational Research.* (Edited by Frank W. Banghart.) Bloomington, Ind.: Phi Delta Kappa (Eighth Street and Union Avenue), 1960. Chapter 1, p. 1-21.

FLAGLE, CHARLES D.; HUGGINS, W. H.; and ROY, R. H., editors. *Operations Research and Systems Engineering.* Baltimore: Johns Hopkins Press, 1960. 889 p.

FRIEDBERG, R. M. "I. A Learning Machine." *IBM Journal of Research and Development* 2: 2-13; January 1958.

FRIEDBERG, R. M.; DUNHAM, B.; and NORTH, J. H. "II. A Learning Machine." *IBM Journal of Research and Development* 3: 282-87; July 1959.

GELERNTER, H. L., and ROCHESTER, N. "Intelligent Behavior in Problem-Solving Machines." *IBM Journal of Research and Development* 2: 336-45; October 1958.

GOETHALS, GEORGE W. "A Framework for Educational Research." *Harvard Educational Review* 28: 29-43; Winter 1958.

GOODE, CECIL E. *Personnel Research Frontiers.* Chicago: Public Personnel Association (1313 East Sixtieth Street), 1958. 176 p.

GRILICHES, ZVI. "Hybrid Corn: An Exploration in Economics of Technological Change." *Econometrica* 25: 501-22; October 1957.

HARRIS, DALE B. *Recent Research and Its Implication for Teacher Education.* Address to the Twelfth Annual Meeting of the American Association of Colleges for Teacher Education, February 11, 1960. State College: Pennsylvania State University, 1960. 14 p. (Mimeo.)

HELMER, OLAF, and RESCHER, NICHOLAS. "On the Epistemology of the Inexact Sciences." *Management Science* 6: 25-52; October 1959.

HOVLAND, CARL I. "Computer Simulation of Thinking." *American Psychologist* 15: 687-93; November 1960.

HUNT, HEROLD C. "Educational Research and National Education Policy." *Journal of Educational Research* 49: 641-48; May 1956.

JOHNSON, ELLIS A. "The Long-Range Future of Operations Research." *Operations Research* 8: 1-23; January-February 1960. (a)

JOHNSON, ELLIS A. "Operations Research in Science and Technology." *Operations Research and Systems Engineering.* (Edited by Charles D. Flagle, W. H. Huggins, and R. H. Roy.) Baltimore: Johns Hopkins Press, 1960. Chapter 3, p. 28-57. (b)

KARLIN, SAMUEL. *Mathematical Methods and Theory in Games, Programming, and Economics.* Cambridge, Mass.: Addison-Wesley Publishing Co., 1959. Vol. 1, 433 p., Vol. 2, 386 p.

KEEZER, DEXTER M. "The Outlook for Expenditures on Research and Development During the Next Decade." *American Economic Review* 50: 355-69; May 1960. (a)

KEEZER, DEXTER M. "Research and Technology: A New Era Begins." *Management Review* 49: 23-27; 62-72; February 1960. (b)

KERSHAW, J. A., and MCKEAN, R. N. *Systems Analysis in Education.* RM-2473-FF. Santa Monica, Calif.: RAND Corporation, October 30, 1959. 64 p.

KIDD, CHARLES V. *American Universities and Federal Research.* Cambridge, Mass.: Harvard University Press, 1959. 272 p.

LACHMAN, ROY. "The Model in Theory Construction." *Psychological Review* 67: 113-29; March 1960.

LATIL, PIERRE DE. *Thinking by Machine; A Study of Cybernetics.* Translated by Y. M. Golla. Boston: Houghton-Mifflin Co., 1957. 353 p.

LERNER, DANIEL, editor. *Evidence and Inference.* Essays originated in the Hayden Colloquium on Scientific Concept and Method, Massachusetts Institute of Technology. Glencoe, Ill.: Free Press, 1959. 164 p.

LEVIN, SAMUEL M. "John Dewey's Evaluation of Technology." *American Journal of Economics and Sociology* 15: 123-36; January 1956.

MACARTHUR, R. S. "Organization for Educational Research in Universities of Midwestern United States." *Alberta Journal of Educational Research* 4: 131-41; September 1958.

MCCONNELL, THOMAS R.; SCATES, DOUGLAS E.; and FREEMAN, FRANK N. *The Conceptual Structure of Educational Research.* Supplementary Educational Monographs, No. 55. Chicago: University of Chicago, Department of Education, May 1942. 47 p.

MACHOL, ROBERT E., editor. *Information and Decision Processes.* New York: McGraw-Hill Book Co., 1960. 185 p.

MILLER, GEORGE A.; GALANTER, EUGENE; and PRIBRAM, K. H. *Plans and the Structure of Behavior.* New York: Henry Holt & Co., 1960. 226 p.

MILLER, HARRY K., JR. *A Study of the Field Service and Research Units of Ten Schools of Education.* Stanford, Calif.: Stanford University, School of Education, 1958. 489 p. (Mimeo.)

ORCUTT, GUY H. "Simulation of Economic Systems." *American Economic Review* 50: 893-907; December 1960.

PHILLIPS, BEEMAN N. "Survey of Research Personnel, Facilities and Activities in State Departments of Education." *Journal of Educational Research* 51: 43-45; September 1957.

REISS, RICHARD F. "The Digital Simulation of Neuro-Muscular Organisms." *Behavioral Science* 5: 343-58; October 1960.

ROSENBLATT, FRANK. "The Perceptron: A Probabilistic Model for Information Storage and Organization in the Brain." *Psychological Review* 65: 386-408; November 1958.

RYANS, DAVID G. "Are Educational Research Offices Conducting Research?" *Journal of Educational Research* 51: 173-83; November 1957.

SCHULTZ, THEODORE W. "Investment in Man: An Economist's View." *Social Service Review* 33: 109-17; June 1959.
SCHWAB, JOSEPH J. "What Do Scientists Do?" *Behavioral Science* 5: 1-27; January 1960.
SHOCKLEY, WILLIAM. "On the Statistics of Individual Variations of Productivity in Research Laboratories." *Proceedings of the Institute of Radio Engineers* 45: 279-90; March 1957.
SHUBIK, MARTIN. "Bibliography on Simulation, Gaming, Artificial Intelligence and Allied Topics." *Journal of the American Statistical Association* 55: 736-51; December 1960.
SIEGEL, IRVING H. "The Role of Scientific Research in Stimulating Economic Progress." *American Economic Review* 50: 340-45; May 1960.
SIMONS, JOSEPH H. "Scientific Research in the University." *American Scientist* 48: 80-90; March 1960.
SUITS, C. GUY. "Opportunity for Basic Research in Industry." *Proceedings of a Conference on Research and Development and its Impact on the Economy.* National Science Foundation Publication No. 58-36. Washington, D.C.: Superintendent of Documents, Government Printing Office, 1958. p. 87-102.
TAYLOR, CALVIN W., editor. *Research Conference on the Identification of Creative Scientific Talent.* Salt Lake City: University of Utah Press, 1956. 268 p.
TAYLOR, CALVIN W., editor. *Second Research Conference on the Identification of Creative Scientific Talent.* Salt Lake City: University of Utah Press, 1958. 255 p.
TAYLOR, CALVIN W., editor. *Third Research Conference on the Identification of Creative Scientific Talent.* Salt Lake City: University of Utah Press, 1960. 334 p.
THISTLETHWAITE, DONALD L. "College Environments and the Development of Talent." *Science* 130: 71-76; July 10, 1959.
THOMSON, GEORGE. "The Two Aspects of Science." *Science* 132: 996-1000; October 14, 1960.
TIEDEMAN, DAVID V., and COGAN, MORRIS L. "New Horizons in Educational Research." *Phi Delta Kappan* 39: 286-91; March 1958.
TRAVERS, ROBERT M. W. *An Introduction to Educational Research.* New York: Macmillan Co., 1958. 446 p.
TRAXLER, ARTHUR E. "Some Comments on Educational Research at Midcentury." *Journal of Educational Research* 47: 359-66; January 1954.
ULICH, ROBERT. *On the Reform of Educational Research.* Occasional Pamphlets No. 2. Cambridge, Mass.: Harvard University, Graduate School of Education, 1937. 26 p.
WALKER, HELEN M. "Methods of Research." *Review of Educational Research* 26: 323-43; June 1956.
WALKER, HELEN M. "Preparation of Research Workers in Education." *Elementary School Journal* 58: 9-15; October 1957.
WEISS, PAUL. "Knowledge: A Growth Process." *Science* 131: 1716-19; June 10, 1960.
WEITZ, HENRY. "A Survey of Student Personnel and Educational Research Facilities." *American Psychologist* 12: 654-58; October 1957.

Additional References

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE. "Instrument Issue." *Science* 132: 1089-1208; October 21, 1960.
CLARKSON, G. P. E., and SIMON, H. A. "Simulation of Individual and Group Behavior." *American Economic Review* 50: 920-32; December 1960.
CRONBACH, LEE J., and GLESER, G. C. *Psychological Tests and Personnel Decisions.* Urbana: University of Illinois Press, 1957. 165 p.
GULLIKSEN, HAROLD. *Mathematical Solutions for Psychological Problems.* Princeton, N.J.: Princeton University and Educational Testing Service, 1958. 54 p.
KLOPSTEG, PAUL E. "The Indispensable Tools of Science." *Science* 132: 1913-22; December 30, 1960.
NATIONAL SCIENCE FOUNDATION. *Bibliography on the Economic and Social Implications of Scientific Research and Development.* Publication No. 59-41. Washington, D.C.: Superintendent of Documents, Government Printing Office, 1959. 53 p.
SHUMSKY, ABRAHAM. "Teachers Explore Their Attitudes Toward Research." *Educational Research Bulletin* 37: 31-38, 56; February 12, 1958.

STEIN, MORRIS I., and HEINZE, S. J. *Creativity and the Individual: Summaries of Selected Literature in Psychology and Psychiatry.* Glencoe, Ill.: Free Press, 1960. 428 p.

SYMONDS, PERCIVAL M. "The Organization of Educational Research in the United States." *Harvard Educational Review* 27: 159-67; Summer 1957.

TYLER, RALPH W. "The Contribution of the Behavioral Sciences to Educational Research." *First Annual Symposium on Educational Research.* (Edited by Frank W. Banghart.) Bloomington, Ind.: Phi Delta Kappa (Eighth Street and Union Avenue), 1960. Chapter 4, p. 55-70.

CHAPTER II

The Philosophy of Science in Educational Research

MICHAEL SCRIVEN

THIS CHAPTER endeavors first to indicate where problems in educational research arising out of the philosophy of science are crucial. It also identifies those sources which provide a background in philosophy of science for workers in the "sensitive" areas. Particular attention is given to work of the last three years, inasmuch as this subject was discussed by Brodbeck in the REVIEW in 1957. Here, however, a somewhat different perspective on the topics discussed by Brodbeck is offered.

Areas of Relevance

Evaluation

A professional logician observing educational research of the last three years is at once struck by certain similarities which exist between it and other fields of contemporary research. An analogy between research in educational areas and research in psychotherapeutic areas holds with respect to the difficulty of constructing valid experimental designs. Both present a number of crucial variables, consequent difficulty of performing statistical analysis, and elusiveness of reliable measures for those variables. Both fields involve value judgments, even moral value judgments, in a number of experimental designs and in areas where experimental investigation is highly desirable.

The moral issues arise in connection with problems of manipulating the subjects appropriately in order to obtain valid experiments. More importantly, however, they arise with respect to the interpretation of the results as a basis for action within the profession itself. Examples are work on the "gifted" student, "adequate representation" of lower economic classes in the parentage of the high-school groups, the "appropriateness" of counseling and guidance procedures, the evaluation of colleges and high schools on a comparative or an absolute basis, the construction of effective disciplinary procedures, the introduction of automatic teaching machines, the "obligation" of the states or the federal government to finance or desegregate education, the separation of superior students into different sections and the associated acceleration procedures, and the interpretation of "creativity." These examples appeared on a survey of the REVIEW of the last few years. In all these cases, the authors of the chapters in question are consciously or unconsciously committed to moral value judgments, whichever interpretation they make of the relevant phrases.

One can, of course, give a purely operational, non-value-impregnated

definition of the term *superior college*, for example, perhaps by giving a simple index involving the proportion of its graduates who proceed to post-graduate work, who become highly thought of in their communities, or whose names appear in *Who's Who in America*. To do this is simply to postpone the uncovering of the assumption by one step. Such an index can be justified only by an analysis of the desirability of such achievements by the graduates. Those achievements must be assessed as being not merely the desired goals of the average college president, college faculty member, or college student, but also as being for the good of the community as a whole. Making such assessments means, essentially, making moral value judgments of these attainments.

Despite the obviousness of this point, much research continues which employs criteria that would not survive five minutes of critical explicit discussion. The explanation is simple. A strong tradition in the history of psychology separates empiricism from ethics, and the average researcher feels completely insecure when he discovers that his criteria involve ethical variables. Either he does not allow himself to perceive this fact, or, if he does perceive it, he says nothing about it.

He may, of course, turn his attention to variables which do not involve ethical components. In educational research this recourse rules out the most interesting problems of all, some of which have been mentioned. The philosopher of science has a role to play in helping the educational researcher with this dilemma, and in recent years extraordinary progress has been made toward development of a rational foundation for ethical judgment. Much of this work is yet unpublished, but some of it is referred to here (Baier, 1958; Brandt, 1959; Edel and Edel, 1959).

Thus it might be said that the defects in the utilitarian position, which have for so long encouraged research into nonrational ethics (the emotivist theory, for example), are now patched up, and it is possible to give a satisfactory, consistent, and non-question-begging utilitarian ethic. To disagree with the assertion just made is to disagree at a level and on grounds which provide little consolation for those who insist on the necessity for theological axioms in ethics. One of the most profound contributions which the philosophy of science has to make to educational research lies in the objectification of value judgments, especially social value judgments, that is, moral value judgments (on the utilitarian assumption).

Descriptive research in education is only part of the story. The most interesting results in the field, from the point of view of social action, concern causal analysis. When problems of causation in the social sciences are met with, difficulties of a kind quite unlike those in the physical sciences are encountered. Recent years have seen, in the philosophy of science, the development of an acute awareness of the important differences between the physical and the social sciences apart from that to which our attention has been called so frequently, namely, the involvement, in certain subareas of the social sciences, of value judgments.

Explanation

The most interesting work in connection with this discrimination between the physical and social sciences has occurred in the philosophy of history. In several recent articles, the most important of which were collected along with background readings in Gardiner's (1959) anthology, a group of philosophers of science elaborated the differences between physical and humanistic explanations. The ways in which this discussion of historical explanation can be transposed to the field of educational research have not yet been spelled out. Even to transpose them into the general area of scientific psychology is an important task still awaiting the attention of logicians.

Certain striking points, however, can be made. In the first place, the idea of explanation as deduction from true generalizations no longer holds (Dray, 1957). (This conclusion is not shared by the present reviewer's predecessor.) The abandonment of this view of scientific explanation is due partly to a realization that it is not attained by most physical explanations, and partly to a realization that the explanations, in history and elsewhere, of behavior of human beings are highly informative and, in a certain sense, fully complete, although these explanations are not deductions from true generalizations.

This sounds like a logician's squabble; but, to give one example of its significance for the social sciences, it follows from this and certain other considerations of a fairly acceptable kind, that the entire Hullian tradition of searching for mathematico-deductive theories of human behavior is a waste of time. (This is not to say that it was a waste of time when it was first done.) If the present reviewer reads the signs aright, there will inevitably be, in the ensuing decades, a concentration on local rather than global theories of behavior and an emphasis on work using our present conceptual terminology rather than on introduction of new jargons.

It is not irrelevant to a consideration of whether this is a fair prophecy to note in the last few years, within the field of psychology, an increasing acceptance of the criticisms of the Hullian and post-Hullian attempts at systematic theories of behavior put forward by Koch (1954) and others. Thus great importance must be attached to recognizing that the search for adequate causal analyses of human behavior does not lead inevitably, or even appropriately, to the development of axiomatic supertheories.

Causation

The belief of Russell (1953) and others that the use of causation in science is a sign of immaturity was widely accepted among traditional philosophers of science of the period 1925 to 1955. Where use of causation was found, it was considered a crutch with which the subject could limp on to better days. It now seems clear that the role of causal analysis,

although indeed minimal in such areas as theoretical physics in which exhaustive and effective mathematical laws are available, is indispensable both in the *application* of advanced sciences and, independently, in a *formulation* of the knowledge of the less theoretical sciences. Moreover, cogent reasons exist for supposing that there are certain sciences—among them large parts of the social sciences including parts of the educational field—where no expectation whatsoever of eventual development of abstract theories is appropriate. Hence, there is every reason to expect that large and respectable parts of science will continue to employ causal claims rather than precise systematized laws.

Naturally, this leads one's attention to a more careful analysis of the concept of cause. Fundamentally, a cause is a miniature explanation—not an *incomplete* explanation, but a small explanation. Particularly, it must not be taken to be the same as a sufficient condition, or a necessary condition, or as committing its employer to a belief in determinism. Cause is an identifying or selecting or focusing or differentiating notion, which operates somewhat as a premise in the analysis of deductive arguments. It can be understood only in the context of a particular inquiry, where the contrasts that it is used to educe can be understood; from a formal point of view, any one of 40 variables may be in the same position as far as a particular effect goes, but in the context of a particular inquiry one, and only one, of these may properly be called the cause. (It is thus a notion from pragmatics, rather than syntactics, to give it a proper place in the over-all field of logic.)

The empirical elements involved in isolating the candidates for a causal assertion still raise important problems of experimental design. How is a distinction to be made between a causal connection and a mere correlation? Brodbeck (1957), following Braithwaite (1953), proposed that the distinction lies in the answer to the question of whether the alleged connection can be deduced from some other law or laws: if it can, it is causal; if it cannot, it is a mere correlation. This is too simple, unfortunately. The problem still remains of whether the laws from which it is deduced are themselves causal laws or merely correlational laws. A complete answer requires a study of the role of the connection in those theories, usually of a very tentative kind, which could be said to provide an explanation of them.

Experimentally, the problem does not require the sophisticated analysis demanded by the philosopher. Nevertheless, it presents some intriguing difficulties. Suppose a certain treatment is applied to the experimental group, for example, intensive tutorial assistance, and that a perfectly matched control group ultimately shows itself to have attained equivalent improvement over a certain interval. This result is normally taken to demonstrate an absence of causal efficacy on the part of the experimental variable. It does not. It may well be that the experimental variable does produce significant improvement, but the described design (despite its Utopian assumption of perfectly matched controls) does not prove the

fact (Hook, 1959). This is a practical experimental result which arises from the logician's investigations. Similar practical consequences are found when applied medicine is turned to and the current status of the placebo studies is examined; it is not realized that a single control study cannot demonstrate any placebo effect.

Evidence

A great revolution in social science has been taking place, particularly throughout the last decade or two. Many educational researchers are inadequately trained either to recognize it or to implement it. It is the revolution in the concept of evidence. The problems that are faced in experimental design in the social sciences are quite unlike those of the physical sciences. Problems of experimental design have had to be solved in the actual conduct of social-science research; now their solutions have to be formalized more efficiently and taught more efficiently. Looking through issues of the REVIEW OF EDUCATIONAL RESEARCH, one is struck time and again by the complete failure of the authors to recognize the simplest points about scientific evidence in a statistical field. The fact that 85 percent of National Merit Scholars come from small families and that over 70 percent are first-born is quoted as if it means something, without figures for the over-all population proportion in small families and the over-all population proportion that is first-born.

The simple fact is this: by minimum acceptable research standards, 95 percent of the work in the field of psychotherapy that is concerned with causal analysis is, by either theoretical or practical standards, invalid or trivial. In educational research the situation is no different. So far as descriptive work goes, the situation is better; but this is less interesting (Hook, 1959). One cannot apply anything one learns from descriptive research to the construction of theories or to the improvement of education without having some causal data with which to implement it. There is no need for educational researchers to feel inferior because of this situation, but they should feel dissatisfied.

Corresponding to this persistent lack of sensitivity to minimum standards of good evidence in a multivariable field, there is the persistent failure to face up to the problems arising from the fact that the application of educational theories has morally significant consequences. In guidance and counseling, for example, which are no different in this respect from research into the education of the gifted or other fields that could be cited, two senior editors are found agreeing that "authors make many philosophical assumptions both explicit and implicit but usually neither examine nor test them" (Wilkins and Perlmutter, 1960).

From the logician's point of view, then, gross deficiencies of self-awareness in educational research exist, although techniques are available for handling most of these difficulties. As long as those in education allow their own institutions to put out written and cinematographic

propaganda which seeks support for higher education by arguing that the average income of graduates is so much higher than that of non-graduates as to more than reimburse them for the cost of higher education within very few years (without adducing any grounds whatsoever for supposing that this connection is in fact a causal connection and is not, for example, due to the higher income group of the families from which college students come)—so long will they fall short of achieving maturity for their own subject. This is an excellent example of an argument which is scientifically unsound and significantly immoral, since it encourages people to spend money on the basis of a belief which is not known to be well founded.

Sundry Issues

The confusion about what constitutes an adequate definition persists, and has continued to be discussed during the last three years (Feigl, Scriven, and Maxwell, 1958). As in the case of explanation, important advances seem imminent. It has been realized that the significant terms of theoretical physics are not amenable to explicit definition, or indeed to definition in any precise and condensed way. With this collapse of the idol around which most of the theology of operationism and reduction sentences was built, there has come a more realistic approach to definition. As Mandler and Kessen (1959), in a most encouraging book, have stressed, there is only one important standard for good definitions, and that is inter-user reliability in their use in a given verbal or empirical context. That is, the important procedure in the introduction of a new term is provision for adequate training in its use for the reader.

Typically, such training can be provided by giving many examples and some loose rules to serve as guidelines for the term's use. But the word *loose* here must not be misunderstood. A good definition, that is, a good explanation of the meaning of a term, gives extremely high reliability in its use. Whenever this can be done by explicit simple definitions, then it should; with the introduction of new terms this is usually possible. But it should not be dismaying to discover that some theoretical concepts, new and old, have acquired too great a burden of meaning for any explicit definition to encompass. In those cases it must not be supposed that the use of a single example (implicit definition) or a rough analogy will be adequate. If the introduction of the new term is to be justified, rather than the use of a concatenation of old ones, then it must be done properly, and this is a lengthy business.

To the logician it is clear that in educational research, as in the social sciences generally, there is still a pathetic tendency to identify the use of a jargon with the possession of a science. Terms such as *consonance* and *dissonance* in social psychology, *model, meaningful, intellective, normative, methods, scale, role, motivation, cross-cultural,* and *action research* are still used (in the special senses which are relevant to educational

research) in sloppy, unilluminating, and irresponsible ways. It could almost be said that, outside of statistics, terms which have been introduced specifically for educational research have done more to confuse than to clarify. That such a cynical generalization should have validity ought to make those concerned think three times before introducing new terms or new senses of old terms.

Another area where logical analysis is appropriate is discussion of objectivity, prejudice, bias, and similar concepts (Gardiner, 1959). There is still a pervasive tendency to suppose that the existence of a causal explanation for everybody's beliefs means that there is not a rationally superior justification for some of those beliefs. This is the old fallacy of the sociology of knowledge, and its ghost should have been long since laid (Hampshire, 1959; Hook, 1958).

Discussion of brainwashing, subliminal perception, and motivation research in advertising psychology and psychopathology has important consequences for the thoughtful student of education. What distinguishes brainwashing from education? What is indoctrination? What is propaganda? To what extent are educators in fact supporting this kind of influencing procedure in their school system with ritual observance of allegiance, emphasis on peer-group attitudes as a criterion for social action, and the like? Analytical thinking on this kind of subject is still badly needed (Kinkead, 1959).

Finally, careful investigation of the possibility and success of separate training in courses in logic, scientific method, critical thinking, and investigation of the extent to which such training transfers or generalizes to other fields is needed. Somehow it must be ensured that at a much earlier stage in their development, students become self-consciously aware of the process of education and its presuppositions and justifications, so that they will eventually be in a position to improve it in the many ways it stands in sore need of improvement.

General References

Many of the topics discussed here, and certain others of interest to the researcher (for example, logic of discovery), are discussed in compendious books that appeared during the last three-year period. Reference to these will give an interested worker a picture of the present range of relevant thought in the philosophy of science (Gibson, 1960; Hanson, 1958; Klibansky, 1958; Nagel, 1960; Popper, 1959).

Bibliography

BAIER, KURT. *The Moral Point of View; A Rational Basis of Ethics.* Ithaca, N.Y.: Cornell University Press, 1958. 326 p.

BRAITHWAITE, RICHARD B. *Scientific Explanation.* Cambridge, England: Cambridge University Press, 1953. 376 p.

BRANDT, RICHARD B. *Ethical Theory*. Englewood Cliffs, N.J.: Prentice-Hall, 1959. 538 p.

BRODBECK, MAY. "The Philosophy of Science and Educational Research." *Review of Educational Research* 27: 427-40; December 1957.

DRAY, WILLIAM H. *Laws and Explanation in History*. Oxford: Oxford University Press, 1957. 174 p.

EDEL, MAY, and EDEL, ABRAHAM. *Anthropology and Ethics*. Springfield, Ill.: Charles C Thomas, 1959. 250 p.

FEIGL, HERBERT; SCRIVEN, MICHAEL; and MAXWELL, G., editors. *Concepts, Theories, and the Mind-Body Problem*. Minnesota Studies in Philosophy of Science. Minneapolis: University of Minnesota Press, 1958. Vol. 2, 553 p.

GARDINER, PATRICK, editor. *Theories of History*. Glencoe, Ill.: Free Press, 1959. 549 p.

GIBSON, QUENTIN B. *The Logic of Social Enquiry*. London: Routledge & Kegan Paul, 1960. 213 p.

HAMPSHIRE, STUART. *Thought and Action*. London: Chatto & Windus, 1959. 276 p.

HANSON, NORWOOD R. *Patterns of Discovery*. Cambridge, England: Cambridge University Press, 1958. 240 p.

HOOK, SIDNEY, editor. *Determinism and Freedom in the Age of Modern Science*. New York: New York University Press, 1958. 237 p.

HOOK, SIDNEY, editor. *Psychoanalysis, Scientific Method, and Philosophy*. New York: New York University Press, 1959. 370 p.

KINKEAD, EUGENE. *In Every War But One*. New York: W. W. Norton & Co., 1959. 219 p.

KLIBANSKY, RAYMOND, editor. *Philosophy in the Mid-Century: I. Logic and Philosophy of Science*. Florence: La Nuova Italia, 1958. 337 p.

KOCH, SIGMUND. "Clark L. Hull." *Modern Learning Theories*. (Edited by William K. Estes and others.) New York: Appleton-Century-Crofts, 1954. p. 1-176.

MANDLER, GEORGE, and KESSEN, WILLIAM. *The Language of Psychology*. New York: John Wiley & Sons, 1959. 301 p.

NAGEL, ERNEST. *The Structure of Science*. New York: Harcourt, Brace & World, 1960. 618 p.

POPPER, KARL R. *The Logic of Scientific Discovery*. New York: Basic Books, 1959. 479 p.

RUSSELL, BERTRAND. "On the Notion of Cause with Applications to the Free-Will Problem." *Readings in the Philosophy of Science*. (Edited by Herbert Feigl and May Brodbeck.) New York: Appleton-Century-Crofts, 1953. p. 387-407.

WILKINS, WILLIAM D., and PERLMUTTER, BARBARA J. "The Philosophical Foundations of Guidance and Personnel Work." *Review of Educational Research* 30: 97-104; April 1960.

CHAPTER III

Research Methods: Experimental Design and Analysis

RAYMOND O. COLLIER, JR. and DONALD L. MEYER

FOLLOWING the pattern set by Stanley (1957), this chapter omits almost all the references which have been covered by Harman (1958), Grant (1959), and Kogan (1960). Writings which have relevance to or are potentially useful for educational experimentation from either a long-range or a short-range point of view are, in general, noticed. In certain areas of experimental design and analysis, only a representative number of the many papers which actually appeared have been considered.

Design and Analysis of Experiments

Most of the work relative to the design and analysis of experimental results during the last three years has added to and extended standard designs and analyses.

Randomized Blocks, Latin Squares, and Split-Plots

The frequently employed randomized-block design was considered by Sampford and Taylor (1959) for the experimental condition where it is known only that a particular subject's response is greater or less than some value. Treatment effects and bias were estimated, and modified *T*-tests were derived for testing treatment differences.

Mandel (1959) described a method valid for analysis of the Latin-square design under the presence of row-column interaction when the interaction can be represented by a simple multiplicative constant. Under certain experimental circumstances this technique might act to counter some of the behavioral scientists' past objections to the use of Latin-square designs. The modified Latin square was analyzed by means of randomization theory by Rojas and White (1957). For this rarely used design they obtained the expected mean squares under randomization and found the *F*-ratio for treatments to be biased, but with a relatively small magnitude.

The simple split-plot design was studied by Curnow (1957) as used both in a randomized block and in a Graeco-Latin square. For the special case of two split-plot units with possibly unequal error variances, he obtained a test of equality of, and confidence bands for estimating the ratio of, the two split-plot error variances.

A publication which has not received the attention it deserves is Wilk and Kempthorne's (1956) report on the derived-model and randomization theory. They provided randomization analysis of many standard

designs and included expected mean squares (needed in the specification of proper error terms) for various effects in many models under general schemes of sampling and randomization of treatment to experimental unit. Their summary of the role of randomization in experimentation should be of use and interest to many researchers who desire an intensive treatment of this problem.

Designs in Which Treatments Are Applied to Subjects in Sequence

An approach to repeated-measurements experiments, in which more than one treatment is applied to experimental subjects over a period of time, was given by Geisser (1959). His analysis took into account the presence of dependencies among observations on the same subject and provided estimation of treatment effects and a test of significance, a multivariate T^2-test, of treatment effects. Related problems were discussed by Freeman (1957), whose paper dealt with the specification of designs useful in situations where experimental units previously treated in an experiment are employed in a new experiment. He supplied analyses of variance and covariance and gave variances of treatment differences.

The involved task of constructing designs balanced for order effects in repeated-measurements experiments was examined by Bradley (1958). If an even number of treatments are being compared, it is possible to construct a Latin square in which each treatment is preceded by a different treatment in every row (and column if desired). These configurations have been found useful in counterbalancing immediate sequential or other order effects, and Bradley gave simple construction procedures for these designs.

Sampford (1957) offered methods for building and analyzing designs in which estimation and test of direct effects of treatment in the period applied, and also the residual effects on treatments in the following periods, were desired. For treatments applied in sequence to the same subjects, Sampford provided designs in which the residual effect of any treatment appears the same number of times either with each direct effect including itself or with each of the direct effects not including itself.

Factorial Experiments

The last few years have seen increased prevalence of experiments involving factorial arrangement of treatments. Experimenters include many factors, believing they are then studying a process similar to that which they meet in nature. This, of course, is a step away from the one-factor-at-a-time experiment. Many experiments involving several factors were reported, for this seems to be a very useful design in educational research.

A comprehensive listing of plans for full and fractional replication of investigations with up to 256 treatment combinations was provided by

Mitton and Morgan (1959). Dykstra (1959) considered two-level factorials and fractional factorials in which a subset of the treatment combinations was replicated in order to secure an unbiased estimate of error. Birnbaum (1959) provided methods for judging which of certain contrasts may be different from zero in factorial experiments performed without replication. Schwarz (1960) discussed a class of factorial designs for N observations which are distributed over the cells so that the cell frequencies are unequal but the resulting normal equations are explicitly solvable.

The problem of estimating effects, for example, linear and quadratic effects, in a single-factor experiment when the levels of the factor are unequally spaced was dealt with by Robson (1959), who presented a simple method of constructing orthogonal polynomials, with numerical examples. McHugh (1958) discussed Hartley's procedure for testing several effects in the analysis of variance for factorial experiments. This technique involves adjusting the significance levels for testing each effect so that an over-all error rate is not exceeded for all effects. The problems associated with the practice of using a single mean square in testing many effects are considered, and one solution is offered.

Designs Useful in Investigating the Nature and Maximum Values of a Pattern of Response

Of several articles dealing with response surface methodology, the most definitive was that by Box and Draper (1959). Considering the minimization of the integrated mean square error over some experimental region as a basis for the selection of response surface design, they showed that this criterion leads to two separate sets of terms: one involving the variance of the estimated response; the other, the specification bias. The optimum design which minimizes both variance and bias was found to be nearly the same as that given by minimizing bias alone.

Bose and Draper (1959) offered a special group transformation which leads to infinite classes of second-order rotatable designs in both two and three dimensions. Draper (1960) extended this transformation to second-order rotatable designs in four or more dimensions. Gardiner, Grandage, and Hader (1959) proposed several designs for exploring response surfaces when the assumed model is of third order.

DeBaun (1959) observed that the usual second-order designs require at least five levels of each factor and considered three-factor designs which require only three levels of each factor. None of these techniques and designs has been used to any extent in educational experimentation although there are areas such as learning research where their application might be efficient.

Nonlinear models were studied by Box and Lucas (1959). Their problem consisted of assuming a response to be a nonlinear function of either

parameters or variables, and then searching for a pattern of administering treatment combinations so as to allow a precise estimation of the parameters. Applying their approach to educational and psychological experimentation, for example, one might look for a schedule of time points so that observations taken at these points would permit efficient estimation of learning or growth parameters.

Miscellaneous Articles

A few articles not properly classified under the foregoing headings are reviewed in this section.

An important article by Chernoff (1959) contained a thorough, theoretical discussion of sequential experimentation. Since experimenters seldom perform experiments as single, isolated investigations, but rather as links in a chain of research and theory, there should be ready applications of sequential designs, and this particular paper is welcomed as a forerunner of applications to come.

Bechhofer (1960) developed a multiplicative model for factorial experiments where the variance of a variable is under study, giving analyses for testing hypotheses concerning variances. One can think of many educational and psychological investigations where the variance itself is an important variable. Designs which adjust for time trends or changes in a process over time and in which both qualitative and quantitative variables may be studied were presented by Hill (1960). The complexities associated with missing or mixed-up observations were discussed by Kramer and Glass (1960) for the Latin-square design and by Biggers (1959) for several designs.

Bradley and Schumann (1957) and Schumann and Bradley (1957, 1959) gave the underlying theory for comparing the sensitivities of two similar experiments, using noncentral variance ratios in both Model I and Model II of the analysis of variance, and discussed its application. The comparison of experiments with different scales of measurement was also discussed.

Inasmuch as most articles on incomplete block designs dealt with methods of constructing classes of partially balanced and balanced designs, they were considered to be of limited general interest and are not included here.

The Analysis of Variance

Scheffé's work on the analysis of variance has already been mentioned. A less extensive survey of analysis-of-variance models, their construction, and their differential aspects was that of Plackett (1960), who gave particular attention to the finite models of Kempthorne, Wilk, Tukey, and Cornfield.

Using matrix methods, Roy and Gnanadesikan (1959a, b) presented a unified general treatment for Model I and Model II in the analysis of variance both for the univariate and the multivariate case. Another comprehensive paper with a nontechnical approach to problems in the analysis of variance was Green and Tukey's (1960). Bankier (1960) proposed an operational method for obtaining the expected mean squares in the analysis of variance and the variances of estimates of variance components for an *r*-way classification.

The components-of-variance model was also considered by Bankier and Walpole (1957) for two-way crossed and nested classifications with proportional subclass frequencies. Useful expected values for various sums of squares were obtained for a variety of models. Likewise, Searle (1958) studied the two-way classification components-of-variance setup. For the unequal frequencies case, he derived the sampling variance of estimates of the components.

In some analysis-of-variance settings, the error components in the underlying model must be assumed to be correlated and to have unequal variances. This problem was treated by several writers, many of whom were motivated by repeated-measurement studies. Two such papers are informative.

Extending Box's original results on the two-way to the *r*-way classification, Bhat (1959) obtained distributions for various sums of squares under the assumption that the error components were correlated with heterogeneous variances. His results are of particular interest to researchers for whom the assumption of independent errors is untenable, for example, in the profile analysis problem and situations where the subject is measured under several conditions.

With different assumptions, Rao (1959) derived estimation and test procedures for various parameters in general linear models. He investigated models in which the observations are assumed to have the multivariate normal distribution with an arbitrary unknown variance and correlation structure estimable from the data. Rao's results, although difficult to apply, make it unnecessary to assume a patterned structure of correlations as is often done, and the repeated-measurement problem is thus given more generality.

With more emphasis on application, Matern (1957) offered a method for obtaining degrees of freedom through a linear combination of the number of squared terms in each component of the sum of squares.

With reference to tests of hypotheses in the analysis of variance, Sutcliffe (1958) concluded that random errors of measurement decrease the sensitivity of the *F*-test of difference among means. Again on tests of hypotheses, Collier (1959) showed that the test of a main effect, e.g., rows, for a two-way classification with interaction in a reparameterized model is equivalent to testing the hypothesis that the average of cell parameters for a row is constant for all rows.

Among investigations of the effects of assumptions in the analysis of

variance, Hack's (1958) paper was of considerable interest. He obtained empirical randomization distributions for row and column F-ratios in a completely randomized two-way layout with one observation per cell. Hack considered two configurations—one showing little deviation from normality and a second more markedly deviating from normality. He obtained 100 random permutations of the observations and compared the upper and lower 5-percent and 10-percent empirical F-points with those of Snedecor's F-distribution. Although agreement was close for the near-normal case, the theoretical F-points for the second case would be underestimates of the true permutation probabilities. Johnson (1958) followed with a theoretical discussion of Hack's investigation.

Srivastava (1959) studied the effects of non-normality on the non-null distribution of the F-statistic in an equal-frequency, one-way classification. Within the limitation of his specification of non-normality, he found that skewness had little effect on the power of the analysis-of-variance F-test, but that extreme deviations in Kurtosis affected the power function in a variable fashion, particularly with small samples.

The Analysis of Covariance

Under certain conditions, the analysis of covariance is a highly useful and effective tool in the interpretation of experimental results. The conditions under which it can be efficiently used were considered at length in the September 1957 *Biometrics*. Most of the papers included were reviewed by Grant (1959) and are not considered here. Unreviewed papers by Zelen (1957), Federer (1957), and Wilkinson (1957) were concerned with covariance in incomplete block designs, in unbalanced classifications, and as related to the incomplete-data problem.

Experimenters who have decried the practice of matching groups on one or more variables as a *substitute* for obtaining random-treatment groups will be buoyed by the results of Finney (1957). He concluded that: (a) the objective matching of groups is practically impossible, (b) the arrangement resulting from a matching procedure hardly qualifies as a random arrangement of units, and (c) the practice leads to a biased F-ratio. The use of a covariance analysis with matching techniques is able to effect little gain in precision.

Nonparametric Techniques in Experimental Design

Although many articles dealt with nonparametric techniques, we consider here only those directly relevant to experimental design.

A theoretical article by Walsh (1959) suggested a class of nonparametric procedures for testing the statistical identity of treatments in randomized blocks. Siegel and Tukey (1960) offered a nonparametric test for testing the null hypothesis that two samples come from the same

population against the alternative that the samples are from populations differing only in variability.

A rank-sum test for comparing each of several treatments against a control in an experiment was proposed by Steel (1959), who also later (1960) advanced a rank-sum test for comparing all pairs of treatments in a one-way classification with equal numbers of observations in each treatment. Van Elteren and Noether (1959) obtained the asymptotic efficiency of the test statistic underlying Durbin's rank analysis for the incomplete block design as compared to the analogous *F*-test in normal theory.

Using theory developed by Roy and Mitra, Hoyt, Krishnaiah, and Torrance (1959) gave the analysis for several hypotheses of interest in a four-way contingency table. Numerical examples were given and extensions to higher-order tables were indicated.

Some Current Thought in Experimental Design

Four basic works present the most incisive and progressive current views on experimental design and perhaps point the direction of future endeavors.

On the one hand, Gridgeman's (1959) re-examination of the problems surrounding Fisher's tea-testing lady will assure experimenters that the "old" controversies in interpreting experimental results have not been resolved. On the other hand, Kiefer, in two challenging papers (1958, 1959) departing from traditional views, compared the optimality properties of classes of designs, such as the Latin-square or balanced incomplete block designs chosen randomly or nonrandomly from these classes. For the designs considered, he concluded that—depending on the objectives of the experimenter, e.g., estimation or hypothesis testing—the symmetrical classical, randomized designs may be nonoptimal, and that nonclassical, nonsymmetrical designs may be optimal. The argument rests, of course, on definitions of optimality (Kiefer presents several), and there seems to be little agreement on this point among either statisticians or experimenters. The development of Kiefer's contributions should be of interest to many researchers.

A long-awaited presentation of a popular technique was offered by Scheffé's (1959) discussion of the theoretical and practical aspects of the analysis of variance, which gave extensive exposition of the various models and analyses used in the interpretation of experimental and survey results. He included finite and infinite models based on fixed, random, or mixed components and independent and dependent components. Scheffé's whole approach was one of rigorous exposition of a method of analysis which has had great utility.

These works reflect interest in examining the philosophy and structure of the design and analysis of experiments. As healthy as such interest is, it will cause the experimenter in time to alter his approach to experimentation.

Concluding Remarks

The foregoing discussion shows an abundance of articles and other writings on experimental design. Among books dealing with experimental design, the analysis of variance, and related topics were those of Chew (1958), Cox (1958), Finney (1960), Freund, Livermore, and Miller (1960), Haggard (1958), Li (1959), Maxwell (1958), Ray (1960), Scheffé (1959), and Williams (1959). Several of these books were reviewed in various journals, and references to reviews are given in the bibliography.

As is always the case, many articles could not be included. A list of the omitted articles may be obtained from the authors.

Bibliography

BANKIER, J. D. "An Operational Approach to the r-Way Crossed Classification." *Annals of Mathematical Statistics* 31: 16-22; March 1960.

BANKIER, J. D., and WALPOLE, R. E. "Components of Variance Analysis for Proportional Frequencies." *Annals of Mathematical Statistics* 28: 742-53; September 1957.

BECHHOFER, ROBERT E. "A Multiplicative Model for Analyzing Variances Which Are Affected by Several Factors." *Journal of the American Statistical Association* 55: 245-64; June 1960.

BHAT, B. R. "On the Distribution of Various Sums of Squares in an Analysis of Variance Tables for Different Classifications with Correlated and Non-Homogeneous Errors." *Journal of the Royal Statistical Society* (Series B, Methodological) 21: 114-19; No. 1, 1959.

BIGGERS, J. D. "The Estimation of Missing and Mixed-Up Observations in Several Experimental Designs." *Biometrika* 46: 91-105; June 1959.

BIRNBAUM, ALLAN. "On the Analysis of Factorial Experiments Without Replication." *Technometrics* 1: 343-58; November 1959.

BOSE, R. C., and DRAPER, NORMAN R. "Second Order Rotatable Designs in Three Dimensions." *Annals of Mathematical Statistics* 30: 1097-1112; December 1959.

BOX, G. E. P., and DRAPER, NORMAN R. "A Basis for the Selection of a Response Surface Design." *Journal of the American Statistical Association* 54: 622-54; September 1959.

BOX, G. E. P., and LUCAS, H. L. "Design of Experiments in Non-Linear Situations." *Biometrika* 46: 77-90; June 1959.

BRADLEY, JAMES V. "Complete Counterbalancing of Immediate Sequential Effects in a Latin Square Design." *Journal of the American Statistical Association* 53: 525-28; June 1958.

BRADLEY R. A., and SCHUMANN, D. E. W. "The Comparison of the Sensitivities of Similar Experiments: Applications." *Biometrics* 13: 496-510; December 1957.

CHERNOFF, HERMAN. "Sequential Design of Experiments." *Annals of Mathematical Statistics* 30: 755-70; September 1959.

CHEW, VICTOR. *Experimental Designs in Industry*. New York: John Wiley & Sons, 1958. 268 p. (See review in *Biometrika* 46: 266-67; June 1959, and *Journal of the American Statistical Association* 54: 320-22; March 1959.)

COLLIER, RAYMOND O., JR., "A Supplementary Note on 'Main Effects and Non-zero Interactions in a Two-way Classification'." *Journal of Experimental Education* 27: 245-46; March 1959.

COX, D. R. *Planning of Experiments*. New York: John Wiley & Sons, 1958. 308 p. (See review in *Biometrika* 46: 492-93; December 1959, and *Psychometrika* 25: 117-18; March 1960.)

CURNOW, R. N. "Heterogeneous Error Variances in Split-Plot Experiments." *Biometrika* 44: 378-83; December 1957.

DEBAUN, ROBERT M. "Response Surface Designs for Three Factors at Three Levels." *Technometrics* 1: 1-8; February 1959.

DRAPER, NORMAN R. "Second Order Rotatable Designs in Four or More Dimensions." *Annals of Mathematical Statistics* 31: 23-33; March 1960.

DYKSTRA, O., JR. "Partial Duplication of Factorial Experiments." *Technometrics* 1: 63-75; February 1959.

FEDERER, WALTER T. "Variance and Covariance Analyses for Unbalanced Classifications." *Biometrics* 13: 333-62; September 1957.

FINNEY, D. J. "Stratification, Balance and Covariance." *Biometrics* 13: 373-86; September 1957.

FINNEY, D. J. *An Introduction to the Theory of Experimental Design.* Chicago: University of Chicago Press, 1960. 232 p.

FREEMAN, G. H. "Some Experimental Designs of Use in Changing from One Set of Treatments to Another: I, II: Existence of the Designs." *Journal of the Royal Statistical Society* (Series B, Methodological) 19: 154-62; 163-65; No. 1, 1957.

FREUND, JOHN E.; LIVERMORE, PAUL E.; and MILLER, IRVING. *Manual of Experimental Statistics.* Englewood Cliffs, N.J.: Prentice-Hall, 1960. 132 p.

GARDINER, D. A.; GRANDAGE, A. H. E.; and HADER, R. J. "Third Order Rotatable Designs for Exploring Response Surfaces." *Annals of Mathematical Statistics* 30: 1082-96; December 1959.

GEISSER, SEYMOUR. "A Method for Testing Treatment Effects in the Presence of Learning." *Biometrics* 15: 389-95; September 1959.

GRANT, DAVID A. "Statistical Methods." *Annual Review of Psychology.* (Edited by P. R. Farnsworth and others.) London: Arthur F. Bird, 1959. p. 131-46.

GREEN, BERT F., JR., and TUKEY, JOHN W. "Complex Analyses of Variance: General Problems." *Psychometrika* 25: 127-52; June 1960.

GRIDGEMAN, N. T. "The Lady Tasting Tea and Allied Topics." *Journal of the American Statistical Association* 54: 776-83; December 1959.

HACK, H. R. B. "An Empirical Investigation into the Distribution of the F-ratio in Samples from Two Non-Normal Populations." *Biometrika* 45: 260-65; June 1958.

HAGGARD, ERNEST A. *Intraclass Correlation and the Analysis of Variance.* New York: Dryden Press, 1958. 171 p. (See review in *Journal of the American Statistical Association* 55: 384-85; June 1960.)

HARMAN, HARRY H. "Statistical Methods." *Annual Review of Psychology.* (Edited by P. R. Farnsworth.) London: Arthur F. Bird, 1958. p. 213-42.

HILL, HUBERT M. "Experimental Designs To Adjust for Time Trends." *Technometrics* 2: 67-82; February 1960.

HOYT, CYRIL J.; KRISHNAIAH, P. R.; and TORRANCE, E. PAUL. "Analysis of Complex Contingency Data." *Journal of Experimental Education* 27: 187-94; March 1959.

JOHNSON, N. L. "Theoretical Considerations Regarding H. R. B. Hack's System of Randomization for Cross-classifications." *Biometrika* 45: 265-66; June 1958.

KIEFER, J. "On the Nonrandomized Optimality and Randomized Nonoptimality of Symmetrical Designs." *Annals of Mathematical Statistics* 29: 675-99; September 1958.

KIEFER, J. "Optimum Experimental Designs." *Journal of the Royal Statistical Society* (Series B, Methodological) 21: 272-304; No. 2, 1959.

KOGAN, LEONARD S. "Statistics." *Annual Review of Psychology.* (Edited by P. R. Farnsworth and others.) London: Arthur F. Bird, 1960. p. 199-224.

KRAMER, CLYDE YOUNG, and GLASS, SUZANNE. "Analysis of Variance of a Latin Square Design with Missing Observations." *Applied Statistics* 9: 43-50; March 1960.

LI, CHING-TS'UNG. *Numbers From Experiments.* Pittsburgh: Boxwood Press, 1959. 106 p.

MCHUGH, RICHARD. "Significance Level in Factorial Design." *Journal of Experimental Education* 26: 257-60; March 1958.

MANDEL, JOHN. "Analysis of Latin Squares with a Certain Type of Row-Column Interaction." *Technometrics* 1: 379-88; November 1959.

MATERN, BERTIL. "128 Note: A Routine for Computing the Degrees of Freedom in Analysis of Variance." *Biometrics* 13: 541-43; December 1957.

MAXWELL, A. E. *Experimental Design in Psychology and the Medical Sciences.* New York: John Wiley & Sons, 1958. 147 p. (See review in *Journal of the American Statistical Association* 54: 512-13; June 1959, and *Psychometrika* 25: 118-19; March 1960.)

MITTON, R. G., and MORGAN, F. R. "The Design of Factorial Experiments: A Survey of Some Schemes Requiring Not More than 256 Treatment Combinations." *Biometrika* 46: 251-59; June 1959.

PLACKETT, R. L. "Models in the Analysis of Variance." *Journal of the Royal Statistical Society* (Series B, Methodological) 22: 195-217; No. 2, 1960.

RAO, C. RADHAKRISHNA. "Some Problems Involving Linear Hypotheses in Multivariate Analysis." *Biometrika* 46: 49-58; June 1959.

RAY, WILLIAM S. *An Introduction to Experimental Design.* New York: Macmillan Co., 1960. 254 p.

ROBSON, D. S. "A Simple Method for Constructing Orthogonal Polynomials When the Independent Variable Is Unequally Spaced." *Biometrics* 15: 187-91; June 1959.

ROJAS, B., and WHITE, R. F. "The Modified Latin Square." *Journal of the Royal Statistical Society* (Series B, Methodological) 19: 305-17; No. 2, 1957.

ROY, S. N., and GNANADESIKAN, R. "I. Some Contributions to Anova in One or More Dimensions." *Annals of Mathematical Statistics* 30: 304-17; June 1959. (a)

ROY, S. N., and GNANADESIKAN, R. "II. Some Contributions to Anova in One or More Dimensions." *Annals of Mathematical Statistics* 30: 318-40; June 1959. (b)

SAMPFORD, M. R. "Methods of Construction and Analysis of Serially Balanced Sequences." *Journal of the Royal Statistical Society* (Series B, Methodological) 19: 286-304; No. 2, 1957.

SAMPFORD, M. R., and TAYLOR, J. "Censored Observations in Randomized Block Experiments." *Journal of the Royal Statistical Society* (Series B, Methodological) 21: 214-37; No. 1, 1959.

SCHEFFÉ, HENRY. *The Analysis of Variance.* New York: John Wiley & Sons, 1959. 477 p. (See review in *Technometrics* 2: 517; November 1960.)

SCHUMANN, D. E. W., and BRADLEY, R. A. "The Comparison of the Sensitivities of Similar Experiments: Theory." *Annals of Mathematical Statistics* 28: 902-20; December 1957.

SCHUMANN, D. E. W., and BRADLEY, R. A. "The Comparison of the Sensitivities of Similar Experiments: Model II of the Analysis of Variance." *Biometrics* 15: 405-16; September 1959.

SCHWARZ, GIDEON. "A Class of Factorial Designs with Unequal Cell-Frequencies." *Annals of Mathematical Statistics* 31: 749-55; September 1960.

SEARLE, S. R. "Sampling Variances of Estimates of Components of Variance." *Annals of Mathematical Statistics* 29: 167-78; March 1958.

SIEGEL, SIDNEY, and TUKEY, JOHN W. "A Nonparametric Sum of Ranks Procedure for Relative Spread in Unpaired Samples." *Journal of the American Statistical Association* 55: 429-45; September 1960.

SRIVASTAVA, A. B. L. "Effect of Non-normality on the Power of the Analysis of Variance Test." *Biometrika* 46: 114-22; June 1959.

STANLEY, JULIAN C., JR., "Research Methods: Experimental Design." *Review of Educational Research* 27: 449-59; December 1957.

STEEL, ROBERT G. D. "A Multiple Comparison Rank Sum Test: Treatments Versus Control." *Biometrics* 15: 560-72; December 1959.

STEEL, ROBERT G. D. "A Rank Sum Test for Comparing All Pairs of Treatments." *Technometrics* 2: 197-208; May 1960.

SUTCLIFFE, J. P. "Error of Measurement and the Sensitivity of a Test of Significance." *Psychometrika* 23: 9-17; March 1958.

VAN ELTEREN, PH., and NOETHER, G. E. "The Asymptotic Efficiency of the X_r^2-Test for a Balanced Incomplete Block Design." *Biometrika* 46: 475-77; December 1959.

WALSH, JOHN E. "Exact Nonparametric Tests for Randomized Blocks." *Annals of Mathematical Statistics* 30: 1034-40; December 1959.

WILK, MARTIN B., and KEMPTHORNE, OSCAR. "Derived Linear Models and Their Use in the Analysis of Randomized Experiments." *WADC Technical Report* 2: 55-244; March 1956.

WILKINSON, G. N. "The Analysis of Covariance with Incomplete Data." *Biometrics* 13: 363-72; September 1957.

WILLIAMS, EVAN J. *Regression Analysis.* New York: John Wiley & Sons, 1959. 214 p. (See review in *Journal of the American Statistical Association* 55: 616; September 1960.)

ZELEN, MARVIN. "The Analysis of Covariance for Incomplete Block Designs." *Biometrics* 13: 309-32; September 1957.

CHAPTER IV

Research Tools: Statistical Methods

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THAT THE RATE of growth of statistical methodology is a positively accelerated phenomenon would seem to be true when one compares the amount of published material during the last three years to the quantity appearing during each of the several preceding three-year intervals. More than 1200 references were located, and about 450 have been included, whereas 216 references were noted in the corresponding chapter of the December 1957 REVIEW by Michael, Kaiser, and Clark.

Their pattern of organization and coverage is followed here. Statistical methods especially applicable to test construction, analysis, and evaluation are deferred for a future issue on educational and psychological testing. The period covered is essentially that between July 1957 and July 1960.

The chapter is organized as follows: after a review of recent books, attention is devoted to (a) general developments in statistical theory with particular stress on contributions to statistical inferences involving parametric procedures; (b) recent advances in the theory and application of chi-square and contingency tables; (c) published research concerning the binomial, Poisson, and multinomial distributions; (d) innovations and modifications in nonparametric theory and techniques; (e) developments in regression and correlation theory, including curve fitting; and (f) methodological advances in factor analysis.

The reader is urged to consult other chapters—especially the one on experimental design—to complete his coverage of other statistical areas such as analysis of variance and data-processing techniques. The excellent critiques of research in statistical methodology by Harman (1958), Grant (1959), and Kogan (1960) in the *Annual Review of Psychology* should not be overlooked.

Books

Scores of books on statistical methodology and experimental design appeared. Kendall and Buckland's (1957) new dictionary of statistical terms, prepared under the auspices of UNESCO, is an indispensable reference aid. For most researchers in education and psychology, books written by behavioral scientists will be the most helpful. Among noteworthy introductory texts are those by Blommers and Lindquist (1960), Diamond (1959), Downie and Heath (1959), Ferguson (1959), Johnson

*The writers are indebted to Cherry Ann Clark for bibliographic assistance in the early stages of preparation of the manuscript. The junior author is primarily responsible for the portion on factor analysis, and the senior author for the other sections.

and Jackson (1959), Mack (1960), Senders (1958), Snedecor (1960), and Walker and Lev (1958). Three lucid statistically oriented books in experimental design are Edwards's (1960) revised text and two new books, by Maxwell (1958) and Ray (1960). Not to be overlooked is a readily comprehended book in nonparametric and shortcut statistics by Tate and Clelland (1957).

At a somewhat more advanced level, but intended for the behavioral scientist, are two general books in quantitative methods: that by Lewis (1960) and a collection of papers from a 1959 Stanford University symposium edited by Arrow, Karlin, and Suppes (1959). At the same level of sophistication are books in multivariate and correlational analysis by DuBois (1957), Ezekiel and Fox (1959), and Haggard (1958).

At a high level of mathematical sophistication are: Kendall and Stuart's (1958) revision of their classical text in advanced statistical theory; a work on the testing of statistical hypotheses by Lehmann (1959b); two contributions to experimental design by Cochran and Cox (1957) and Cox (1958a); three books on multivariate and correlational analysis by Theodore Anderson (1958), Kendall (1957), and Roy (1957); and three philosophically flavored works on probability and inference by Feller (1957), Hogben (1957), and Jeffreys (1957).

Detailed consideration of the theory of measurement and scaling, as well as of individual and group decision processes and information theory, is beyond the scope of this chapter. Nevertheless, attention should be called to a number of significant contributions. In addition to Churchman and Ratoosh's (1959) provocative book concerned with the definition and theory of measurement, three outstanding volumes on scaling appeared: Torgerson's (1958) comprehensive treatment of method; the proceedings of the 1958 Princeton University conference on theory and applications of psychological scaling edited by Gulliksen and Messick (1960); and Thurstone's (1959) important collection of 27 papers on the measurement of values.

In the area of decision making, there appeared, beyond the relatively elementary presentation by Siegel and Fouraker (1960), four volumes: the papers from the 1959 Purdue University symposium on information and decision processes edited by Machol (1960), the presentation of Luce (1959) concerning individual choice behavior within the framework of psychophysics and utility theory, and contributions to decision theory and game theory by Chernoff and Moses (1959), and Luce and Raiffa (1957).

In information and communication theory the most elementary and readable volume was Attneave's (1959). More advanced books were produced by Kullback (1959), who described information theory within a statistical framework, and Middleton (1960), who wrote on statistical communication theory.

Particularly deserving of note is Kemeny, Snell, and Thompson's (1957) short, elementary book that introduces the reader who has studied only

high-school mathematics to the ideas of modern mathematics, including set theory, probability, vector and matrix algebra, and elementary game theory. Diligent reading of this little volume will give educational researchers a grasp of recent advances in statistical thinking. Other books that serve a similar purpose but require greater background in mathematics are, in order of difficulty, Finkbeiner's (1960), Hohn's (1958), Murdoch's (1957), Parker and Eaves's (1960), and Thrall and Tornheim's (1957).

Additional References: Alder and Roessler (1960); Ahmavaara (1957); Ahmavaara and Markkanen (1958); Bailey (1959); Bartlett (1955); Bharucha-Reid (1960); Burington and May (1959); Bush and Estes (1959); Davidson, Suppes, and Siegel (1957); Edwards (1958); L. I. Epstein (1958); Fraser (1958); Garrett (1958); Goldberg (1958); Goldfarb (1960); Grenander (1959); Gumbel (1958); Halmos (1960); Hendricks (1956); Hoel (1960); Hogg and Craig (1959); Johnson and Rao (1959); Levens (1959); McCarthy (1957); Moore (1958); Quenouille (1958); Resnikoff and Leiberman (1957); Riordan (1958); Scheffé (1959); Simon (1957); Sloan (1960); Steel and Torrie (1960); Stephan and McCarthy (1958); Von Mises and Geiringer (1957); Williams (1959a, b).

General Developments Primarily in Parametric Statistics

Emphasis on parametric theory and methods was greater than that given to nonparametric methods. It would appear that the pendulum may have swung in the direction of a continuation of the development and extension of statistical methodology along more traditional lines.

Statistical Inference in General

A number of specific papers in related disciplines concerned with statistical analysis and inference were of interest to the behavioral scientist. Two important contributions were made, for example, in the biological sciences: Chassan (1959) discussed the development of clinical statistical systems for psychiatry, and Emmens (1960) described the role of statistical analysis in physiological research.

General papers concerned with statistical inference were numerous. In an expository article based on Fisher's well-known tea-tasting problem, Gridgeman (1959) defended the rationale of a hypothesized population of identical experiments and argued that consideration should be given to non-null cases in theory testing if one is to construct a satisfactory probabilistic model for sensory-sorting tests and to realize efficiency in various experimental designs. Tukey's (1960) descriptive paper concerning paths along which experimental statistics should develop was directional in emphasis. As a participant in a symposium on scientific method, Taylor (1958) argued against use of statistical-significance tests to verify experi-

mental or research hypotheses that have not been logically evaluated, since absurd hypotheses may be supported. That errors of the first kind may be perpetuated in the psychological literature is evident from a survey by Sterling (1959) of 362 research studies appearing in four journals. In 294 of those studies, significance tests were used with the result that more than 97 percent of the null hypotheses were rejected in the absence of any reports of replication of previously published investigations.

In a historical discourse Welch (1958) reviewed Gosset's work and its impact on statistical thinking and concluded that Student's theory is an improvement in large-sample theory only if the populations sampled approximate Gaussian form. However, in a systematic study involving sampling from a normal, J-shaped, and rectangular distribution embodying the violation of the assumptions of equal variances, Boneau (1960) demonstrated, by and large, a minimal effect on the distribution of *t*'s results. Likewise, Srivastava (1958) showed that for practical purposes the power of the *t*-test is not markedly affected even when samples are selected from substantially non-normal populations. That interest in Student's theory has not diminished is also evident from an important extension of tables of percentage points of Student's *t* distribution by Federighi (1959), White's (1957) *t*-test for a serial correlation coefficient, Moore's (1957) two-sample *t*-test based on the range for pairs of samples between 2 and 20 size, a tabulation by Pachares (1959) of the upper-10-percent points of the Studentized range, and the study by Pillai and Tienzo (1959) of the distribution of the Studentized extreme deviate from the sample mean along with determination of percentage points.

Four other general papers on statistical inference were particularly noteworthy. Interested in ways in which current statistical theories can indicate the extent of uncertainty of an inference, Buehler (1959) developed some validity criteria and attempted to demonstrate the consequences of weakening classical assumptions concerning prior distributions. In his expository paper, Cox (1958c) considered problems of inferential decisions, the sample space of observations, interval estimation, significance tests, and the importance of assumptions. Particularly concerned with the amount of power that can be achieved in significance tests, Lehmann (1958) attempted, in his highly theoretical development, to show how significance levels could be chosen relative to alternative hypotheses of interest.

Good (1958), in a provocative paper, derided the notion that significance must always be precise. He discussed a number of controversial problems, and proposed a rule-of-thumb procedure involving use of a harmonic mean or weighted harmonic mean of the tail-area probabilities associated with various significance tests on the same evidence or data. Consideration was given to judgments about the weights to be employed for combining the results of several different types of tests of statistical significance that are applied to the same set of data (referred to as tests in parallel), in contrast to the more familiar independent tests of significance composed on different sets of data (described as tests in series).

Interval Estimation

Work on statistical estimation, especially interval estimation, was vast. In an expository and highly theoretical paper, Steinhaus (1957) considered in detail the problem of estimation. In an equally abstract paper, Wallace (1959b) described sufficient conditions in the realization of certain properties in a confidence procedure, and found that, if the confidence procedure at level α furnishes with respect to all samples the posterior probability α relative to some prior probability distribution with the parameter space, then there exist no subsets from the sample space for which "the conditional confidence is uniformly less (or greater) than α." Moreover, if a sequence of prior distributions should be employed, a result of wider application will result, although it is slightly weaker. Beale (1960) gave extensive consideration to confidence regions in nonlinear estimation.

To distinguish between fiducial and confidence intervals, Stein (1959) selected an example in which—despite the apparent existence of a large fiducial probability—the chance of the true parameter's being contained within that interval is exceedingly slight. In the instance of significance tests, Anscombe (1957) was able to show that the sampling rule must be considered in order to apply correctly R. A. Fisher's fiducial argument. Supplementing discussion in his recent book (1956), Fisher (1959) compared his fiducial argument with that of Neyman and Pearson concerning confidence intervals, and proposed three requirements for making correct statements regarding mathematical probability. In a highly readable article, Chandler (1957) pointedly differentiated between the concepts of confidence and confidence level on the one hand and significance level on the other, the broad distinction being that of interval estimation and that of testing of hypotheses.

Among papers dealing with more specific problems pertaining to interval estimation were two by Dunn (1958, 1959a) in which she presented methods for constructing sets of simultaneous confidence intervals to include means of variables conforming to a multivariate normal distribution. For a (correlated or uncorrelated) bivariate normal population, Roy and Potthoff (1958) obtained confidence bounds on the vector analogues of the ratio of variances and the ratio of means. Other contributions were those of Tate and Klett (1959), who found optimal confidence intervals for the variance of a normal distribution; Ray (1957), who employed a modified sequential-estimation procedure for the determination of confidence intervals for the mean of a normal population when the variance is unknown; and Banerjee (1959), who developed expressions for the lower bound of confidence coefficients when samples are taken from a non-normal population.

The use of confidence intervals in conjunction with problems in sampling constituted an important feature of two papers. To handle situations in which a randomly selected sample may actually turn out to be undesirable

in a certain respect, Jones (1958) described a procedure that involves the calculation of confidence limits, although the disadvantage exists of having to specify in advance the subclass of inadmissible samples. In determining what the size of a sample should be relative to a designated width of a confidence interval that contains the parameter at a specified probability level, Graybill (1958) proposed a two-step sampling procedure.

Sampling Procedures

Although absent in statistical literature of the behavioral sciences, many articles on sampling appeared in journals on mathematical statistics. For the situation in stratified sampling in which 200 or fewer numbers are to be placed in 10 or fewer groups, W. D. Fisher (1958) devised a practical procedure based on the minimization of variance within groups that served to maximize homogeneity. Likewise, Dalenius and Hodges (1959) furnished means of minimizing variance in finite sampling.

In sampling from both finite and infinite populations, Aggarwal (1959) discussed Bayes and minimax procedures and considered the allocation of total samples with respect to familiar loss and risk functions. Sampling with replacement from finite populations was the subject of a paper by Raj and Khamis (1958), who extended their results to multistage designs. Basu (1958) discussed sampling procedures both with and without replacement, whereas Stevens (1958) limited his consideration to sampling without replacement. In the use of random numbers for the selection of a particular sample, Jones (1959) described ways for determining how many samples will be usable.

For the circumstance in which observations arise from noticeably different populations, Walsh (1959b) defined and described use of a generalized percentage point that not only guards against the acceptance of an erroneous assumption of the presence of a random sample, but also entails only slight penalty when a random sample actually occurs. Gupta and Sobel (1958) developed a sampling procedure for selection of a subset of observations by which all populations exceeding a certain standard are included at a specified probability level. Using a single-sample procedure, Dunnett (1960) described a minimax approach for determining how large a sample must be in order to associate it with the largest of the means of several normal populations of known equal variances and covariances.

Methods of double sampling as well as multistage or sequential sampling were considered in several papers with particular emphasis on development of, or modifications in, estimators. After examining the classical outcomes in theory of regression and estimation from double sampling and extending them to finite populations, Tikkiwal (1960) rela ed various assumptions and determined the resulting influences on the traditional minimum-variance linear unbiased estimators. By means of modifying familiar ratio-type estimators used in sample surveys involving a large

number of strata, Goodman and Hartley (1958) developed an unbiased ratio-type estimator with an exact formula for its variance and compared the precision of their approach to that of other estimators. Mickey (1959) also furnished unbiased ratio and regression estimators in the instance of random sampling without replacement from a finite population. For multistage samples Kish and Hess (1959) described complications arising from the variance of ratio estimators involving two variables. Nanjamma, Murthy, and Sethi (1959) discussed some sampling systems that provide for unbiased ratio estimators, and Murthy (1957) considered both ordered and unordered estimates in sampling without replacement.

Other noteworthy papers on sampling included those of DeGroot and Nadler (1958), who studied the behavior of Wald's sequential probability-ratio test when an erroneous value of variance was taken relative to two applications; of Wormleighton (1960), who furnished a helpful generalization of Stein's (1945) two-sample procedure; of Maurice (1957), who applied Wald's minimax procedure to develop a sequential method of sampling relative to making a decision between two normal populations from information given by two sample means; and of Hack (1958), who, in his empirical study of the distribution of *F*-ratios in samples chosen from non-normal populations, showed that considerable departure from normality may be tolerated.

Point Estimation

Aside from those concerned with sampling techniques, several other theoretically oriented articles appeared that were concerned with estimation. Bahadur (1957) considered unbiased estimates of uniformly minimum variance; Aitchison and Silvey (1958) took up maximum-likelihood estimation of parameters when they were subject to certain restraints; Roy and Chakravarti (1960) discussed ways of estimating the mean of a finite population; Tate (1959) studied unbiased estimation of functions of location and scale parameters for distributions of the exponential type; and Graybill and Deal (1959) showed how a set of random variables could be used to form a weighted combination of unbiased estimators that would in turn be a uniformly improved unbiased estimator.

Estimation in Censored Samples

For the singly censored sample in which measures above a cutting point in an ordered series are omitted or missing, Saw (1959) furnished unbiased estimates of the mean and variance of a normal population. Earlier, Saw (1958) derived moments of sample moments of censored samples selected from a normal population. In the instance of incomplete data associated with both censoring and truncation, Hartley (1958) presented a generalized method of maximum-likelihood estimation embodying simplified computational procedures. Making use of a single auxiliary function

that is conveniently tabulated, A. C. Cohen (1959) described simplified estimators of the mean and variance of a normal distribution from samples that are singly censored or truncated.

The problem of censoring was central to three papers involving use of order statistics (such as percentiles or linear combinations thereof) which are employed in estimation of parameters. Continuing earlier work previously cited in the REVIEW by Michael, Kaiser, and Clark (1957), Sarhan and Greenberg (1958) furnished tables in the instance of samples between 11 and 15 in size for the estimation of location and scale parameters through use of order statistics from both singly and doubly censored samples. Subsequently Sarhan and Greenberg (1959) furnished best linear estimates of location and scale parameters for the rectangular population under conditions of Type II censoring, and included graphs to illustrate the influence of censoring on relative efficiency of estimates. In a related paper Watterson (1959) extended methods of linear estimation to various sorts of censored samples taken from a multivariate normal population—methods which corresponded to those proposed by Sarhan and Greenberg for the univariate case. Finally, through use of order statistics, Dixon (1960) offered simplified methods of estimation from censored normal samples.

Estimation with Order Statistics Without Censoring

Dixon (1957) had earlier furnished several simplified estimates of the mean and standard deviation of a normal population, the efficiencies of which were compared to the sample mean and standard deviation and also to the best linear unbiased estimators. Other papers concerned with order statistics were those of Bose and Gupta (1959), who obtained moments of order statistics for samples from a normal population; of Harter (1959), who made use of "sample quasi-ranges" to estimate the standard deviation of a population; and of Masuyama (1957), who employed the sample range to estimate the standard deviation of the variable of any type of population.

Hypothesis Testing

Although there is a workable distinction between estimation and hypothesis testing in the consideration of problems of statistical inference, the fact that the concepts are not independent is well illustrated in a theoretical paper by Aitchison and Silvey (1960), who considered maximum-likelihood estimation procedures in conjunction with associated tests of statistical significance. In another highly abstract paper, Bulmer (1957) distinguished between the acceptability and the confirmation of a statistical hypothesis depending, respectively, upon whether the hypothesis is supported by a significance test, or comparable procedure, or is rejected. With confirma-

tion defined in terms of a distance function in the hypothesis space that indicates the extent of the discrepancy of any hypothesis from the null hypothesis, all admissible hypotheses can be tested and then classified as either acceptable or unacceptable. If in terms of distance none of the acceptable hypotheses close to the null hypothesis turns out to be "near" to the null hypothesis, it is declared to be confirmed; otherwise the experiment may be regarded as inconclusive, with the null hypothesis unconfirmed. Applications of the rationale are presented along with prior discussion of the acceptability of likelihood criteria. That the standard likelihood-ratio test of the general linear hypothesis possesses a broad class of optimum properties was shown by Lehmann (1959a) to result from the fact that it is uniformly the most powerful invariant.

Testing the hypothesis of homogeneity or hetereogeneity was the subject of several papers. In an important article concerning the testing of homogeneity of alternatives ordered in value, Bartholomew (1959a) stressed that the appropriate test of a hypothesis rests on the careful specification of alternative hypotheses. He proposed that in place of stating the more general hypothesis of inequality among alternative means, for example, one should, in the presence of available information, specify the rank order of the means—a circumstance for which he furnished a solution involving an appropriate one-tail test. Subsequently Bartholomew (1959b) extended his results to more significance levels and gave percentage points for as many as five ordered alternatives. In an empirical investigation of a simple test of the homogeneity for populations composed of normal distributions, Baker (1958) indicated that his test would detect nonhomogeneity when samples are as small as 50.

Related papers were those of Maurice (1958), who investigated the problem of ranking the means of two normal populations when the variances are unknown; Zinger and St-Pierre (1958), who furnished a means of selecting which mean is highest or lowest in three normal populations with known variances; Anscombe and Guttman (1960), who considered rules appropriate in the rejection of outlying values in experimental work when the population variance is known; and Haldane (1959), who analyzed hetereogeneity from the standpoint of estimating the mean and variance of a frequency when it varies throughout a series of samples.

Among other papers concerned with the testing of hypotheses, Gnanadesikan (1959) proposed a test of the hypothesis of equality of more than two variances in more than two univariate normal populations. He extended his results to the multivariate case in which the equality of more than two dispersion matrices is tested against certain alternatives. To determine the equality of variances of two normal populations, Ramachandran (1958b) developed and illustrated a completely unbiased two-sided test with the property of monotonicity and furnished appropriate significance tables. For use when the upper bound of the standard deviation is known for samples from a normal population with unknown means and unknown variances, Colton (1960) suggested a test procedure the power

of which under certain conditions exceeds that of the familiar *t*-test or *F*-test.

For the small-sample situation in which symmetric truncation of the normal distribution has occurred and in which a one-sided test of the hypothesis for the mean of the distribution is made, Aggarwal and Guttman (1959) showed that the loss in power decreases very quickly as a function both of the discrepancy between the alternative value of the mean and that hypothesized and of the distance of the hypothesized mean from the points of truncation. Assuming that the parameters of a population are known, Clark (1957) considered how one-tail and two-tail truncation of a normal population should be carried out relative to prescribed probabilities in order to meet specified requirements for values of sample means.

Other papers concerned with tests of hypotheses were those of Blyth (1958), who considered possible definitions of relative efficiencies when the same hypothesis is tested through use of two sequences of tests and who also calculated relative efficiencies of the Student test and sign test against normal alternatives; of Khatri (1960), who proposed two statistics for testing the hypothesis of equality of ranges in k rectangular populations and included a tabulation of five-percent points; of G. S. James (1959), who put forward a new "exact" test for weighted means that takes into account information furnished by the variances; of Schumann and Bradley (1957), who compared the sensitivities of similar experiments embodying different scales of measurement through tests of hypotheses on the noncentrality parameter involving two noncentral variance ratios; and of Dempster (1958, 1960), who developed a two-sample significance test as an alternative approach to Hotelling's T^2 statistic.

One-Tail Versus Two-Tail Tests

Though less prominent than during other three-year periods, interest in the one-tail versus two-tail controversy persisted. Challenging the three criteria proposed by Kimmel (1957) for determining when one-tail tests can be used, Grant (1959) believed that two of the criteria invited confusion and endangered "the integrity of the rejection level," and Goldfried (1959) somewhat discounted the importance of two of Kimmel's criteria for determining the theoretical predictability and psychological meaning when "unexpected" results occur with a one-tail test. He implied the need in this situation for flexibility in the experimenter's decision of whether or not to use one-tail tests depending on difficulties encountered. Shaklee (1957) disputed Kimmel's statement that there is a doubled probability of commission of a Type I error under a two-tail hypothesis for corresponding significance levels. More important was Kogan's (1960) point that the region of rejection need not be either equally distributed in each tail or concentrated in one tail of the sampling distribution; illustrated in terms of Ramachandran's (1958b) finding that in the customary application of the *F*-test for equality of two independent variances involving equal-tail

areas, the increase in the power of the test is not monotonic as the ratio of the variances of the two populations departs from equality. After pointing out a frequently committed logical error of making a directional statistical decision after the null hypothesis has been rejected in a nondirectional two-sided test, Kaiser (1960c) outlined what he believed to be an appropriate treatment based on Wald's statistical decision function.

Approximation Methods

In a general paper with important implications for and relevance to problems of estimation, Burkholder (1959) systematically and critically examined conditions that allow a best approximation to one distribution function by another distribution of a specified type. Somewhat more specifically, Wallace (1959a) considered formulas that would convert upper-tail values of Student's t distribution, as well as chi-square variates, to normal deviates. To allow for the situation in which a slow-moving trend in the mean of a population serves to introduce bias in customary measures of dispersion such as sample range, sample-mean deviation, and sample variance, Sathe and Kamat (1957) offered four new approximate measures of dispersion derived from successive differences. By means of extending the standardized percentage points of the Pearson Type-IV curve, Merrington and Pearson (1958) succeeded in effecting a close approximation to the distribution of noncentral t.

Useful Tables and Nomographs

Tabular preparations and graphical aids constituted an important part of many of the papers reviewed, and five articles were specifically concerned with such means of presentation. In order to avoid calculations involved in using existing rectangularly distributed observations, Quenouille (1959) made available tables of random observations derived from some standard distributions. The customary need for estimation of parameters in bio-assay problems, a part of the procedure referred to as *normit* analysis, led Berkson (1957) to develop tables for use in estimating the normal distribution function by methods of normit analysis. Subsequently Berkson (1960) provided nomographs in order to fit the logistic function by the method of maximum likelihood.

For the normally distributed random variable with unknown mean and known standard deviation, Barraclough and Page (1959) developed tables to assist in the calculation of Wald's sequential test for the mean of a normal distribution. Particularly helpful in rating techniques is Moonan's (1959) tabulation of the frequencies of the normal distribution relative to selected numbers of class intervals and various sample sizes.

Additional References: Cox (1957); Dwight (1957); B. Epstein (1960); Eisenberg and Gale (1959); Fisher and Cornish (1960); Gjeddebaek

(1959); Gupta (1960); Hogg (1960); Hoyt and Krishnaiah (1958); N. L. Johnson (1958); Katz and Powell (1957); Rider (1957, 1960a, b); Ruben (1960); Tukey (1957); Turner (1960).

Chi-Square, Contingency Tables, and Related Topics

Emphasis on the chi-square statistic and problems posed by use of contingency tables was less than during the previous three-year period.

Contingency Tables

Several noteworthy statistical contributions concerning the use of contingency tables appeared. Extending their well-known paper noticed in the December 1957 issue of the REVIEW, Goodman and Kruskal (1959) further considered in detail the use of measures of association for cross-classification and included a comprehensive bibliography of 150 references. Of particular help to the behavioral scientist is Mayo's (1959) definitive paper concerning ways in which the contingency table can be strengthened as a statistical method. Specifically, Mayo presented recommendations of how chi-square can be employed for small samples in the instance of both attributive and qualitative data, described various approaches to the determination of indices of relationship, discussed at length alternative hypotheses that could be proposed and empirically verified when a significant chi-square value is obtained, enumerated and commented on three approaches to the assessment of higher-order interaction, and finally suggested numerous computational procedures and graphic aids to assist the researcher. In a related paper, Hoyt, Krishnaiah, and Torrance (1959) proposed ways of analyzing complex contingency data.

Concerned with the equivocal results arising out of index of association in contingency tables, Blalock (1958) furnished conditional probabilistic interpretations of coefficients of mean-square contingency and suggested another coefficient as yielding unambiguous results. Making use of work in information theory, Kupperman (1959) proposed a simple coefficient that could be used to test the null hypothesis of independence between row and column classifications and gave a numerical illustration. In the instance of a two-by-two-by-two contingency table, which seems to have been neglected in educational research, Snedecor (1958), in reply to an inquiry, evaluated possible outcomes in the application of alternative chi-square techniques that have been proposed by a number of investigators. Also interested in higher-order contingency tables, Kastenbaum and Lamphiear (1959) succeeded in generalizing Bartlett's method to allow a test of the null hypothesis of the absence of any three-factor interaction in a three-way contingency table, although the computational efforts in estimation of the parameters are almost prohibitive.

Two practical problems in the area of consumer preferences and in the

area of accidents and absenteeism, respectively, prompted papers by R. L. Anderson (1959) and Nass (1959). For the situation in which each of n consumers is asked to rank each of three varieties in a one-two-three order of preference and to record the judgments in a contingency table, Anderson proposed a method of analysis that takes into account the lack of randomness in repeated samplings. Nass described a chi-square for handling small expectations where there is a large number of small samples of accidents or absences for one worker during two or more subperiods of a total period of observation. The test permits inferences of whether the absences or accidents of individual workers can be considered a random sample of the population furnished by marginal totals of the contingency table irrespective of whether these totals correspond to the actual lengths of subperiods or some other assumption concerning the distribution of absences or accidents.

Goodness-of-Fit Applications

Considerable attention was devoted to use of chi-square as an indicator of the degree of goodness-of-fit. After detailed consideration of the previous work of Chernoff and Lehmann, summarized in the December 1957 issue of this REVIEW, Watson (1957) made use of their findings in conjunction with the normal distribution, allowed the class intervals to contain, relative to the sample mean and variance, constant probabilities so as to vary with sampling, and concluded that the chi-square statistic (defined as $\Sigma(f_o\text{-}f_e)^2/f_e$, whereas chi-square stands for the well-known distribution or for a variable with this distribution) is distributed in the Chernoff and Lehmann form. Watson then proceeded to suggest that, in practice, at least 10 class intervals be employed in order that tabular points for the well-known chi-square distribution can be used with an error less than 1 percent. Moreover, discussion was directed to the asymptotic distribution found when fitting is to a normal distribution.

Extending his earlier work on chi-square goodness-of-fit tests to that of fitting an observed distribution to hypothetical continuous distributions, Watson (1958) gave detailed consideration to the number and size of class intervals that should be chosen, and he concluded, contrary to accepted practice, that many, rather than few, class intervals should be employed so that probabilities of inclusion in each interval are approximately equal —a procedure rarely followed by behavioral scientists. More recently Watson (1959) presented some results obtained in the application of chi-square goodness-of-fit tests.

Three other papers pertaining to goodness-of-fit tests were those of Darwin (1958), who employed the method of characteristic functions to effect a correction to the familiar approximations of the chi-square goodness-of-fit criteria for the multinomial distribution; of Chapman (1958), who made a comparative analysis and evaluation of many one-sided good-

ness-of-fit tests; and of Lancaster (1958), who, in addition to considering the relationship between contingency and correlation, proposed a new test for the goodness-of-fit of the bivariate normal distribution.

Miscellaneous Papers

Discussing the Studentized smallest chi-square, Ramachandran (1958a) proposed a method for ascertaining whether among a set of variances the smallest variance is significantly less than a designated variance. To investigate the possibility of the presence of a significant component of a certain type of departure from a hypothesized proportionality when the over-all chi-square reveals nonsignificant heterogeneity, Bodmer (1959) proposed an approximate test for the existence of an extreme frequency in a set of binomial frequencies.

Additional References: Mitra (1958); Sankaran (1959); Stanley (1957).

The Binomial, Poisson, and Multinomial Distributions

Approximately 30 papers concerned with the binomial, Poisson, and multinomial distributions are of interest. On the binomial distribution, the contribution of greatest practical value was that of MacKinnon (1959), who furnished a concise table containing 12 probability levels of the symmetric binomial cumulative distribution for samples ranging in size to 1000, and also included useful approximation methods. Bahadur (1960) considered several approximations to the distribution function of the binomial.

Problems of sampling and estimation were given much emphasis. In order to show the experimenter how large a difference and what confidence coefficient to choose for two binomial populations, Somerville (1957) described a procedure based on the minimax principle and furnished a formula for determining sample size as a function of cost of sampling and the cost of making an erroneous decision. For a family of binomial distributions, DeGroot (1959) developed criteria in order to achieve a workable sequential sampling procedure involving an optimal unbiased estimator of specified values for the parameter. Also concerned with sequential estimation of a binomial parameter, Armitage (1958) described a method to obtain confidence limits for a binomial probability and calculated unbiased estimates of the parameter relative to three sequential designs. Vagholkar and Wetherill (1960) proposed a binomial sequential probability-ratio test which they considered to be the "most economical."

Interval estimation for the parameter in the binomial model was the subject of a paper by Clunies-Ross (1958). In order to determine narrower confidence intervals than those given by classical procedures for the param-

eter of the binomial and Poisson distributions, Stevens (1957) examined several different methods. In the treatment of data embodying binomial responses for which the logistic curve is often used as an alternative to the integrated normal curve, Silverstone (1957) demonstrated that the method embodying maximum likelihood, but not the method of "minimum logit chi-square," furnishes sufficient estimators for the logistic curve and thus strongly recommended the former approach in preference to the latter.

To investigate a practical problem in the combining of accident frequencies, Tanner (1958) used a binomial model. Using a Poisson approximation to the binomial, Buehler (1957) developed, for small probabilities of failure and for samples of moderate size, an approximate method for estimating confidence intervals involving the product of two binomial parameters and furnished tables of intervals relative to the 90-percent and 95-percent confidence levels. For the situation in which an erroneous observation or report yields c defective samples when actually the number is $c + 1$, A. C. Cohen (1960d) employed the method of maximum likelihood to estimate the binomial parameter.

For N binomial samples of the same size, the relative frequencies of which have been ordered in value, Chassan (1960) developed an expression with respect to a significant level α for the upper bound of the probability that the particular observed ordering of values under the null hypothesis could arise by chance. In the comparison of several rates or proportions, such as relative frequency of lung cancer in smokers and nonsmokers, Sheps (1959) examined several models and suggested a general method of estimating parameters. For the difference between binomial probabilities, MacKay (1959) offered asymptotically efficient tests based on the sums of observations.

The estimation of parameters in a truncated, a conditional, and a modified Poisson distribution, respectively, was the subject of three papers by A. C. Cohen (1960a, b, c). Related studies were those of Sprott (1958), who applied the method of maximum likelihood in estimation procedures concerning the Poisson binomial distribution; of Irwin (1959), who considered the estimation of the mean of a Poisson distribution from a sample for which the zero class is absent; of Tate and Goen (1958), who for truncation at the left of this distribution furnished minimum variance unbiased estimates; of Crow and Gardner (1959), who in the estimation of a Poisson variable presented tables of two-sided confidence intervals relative to several confidence coefficients and all values of the variable from 0 to 300; and of Chakravarti and Rao (1959), who provided tables for several small-sample significance tests for the Poisson distribution as well as for two-by-three contingency tables.

Use of the multinomial model in decision making and classification was treated in three papers, those of Bechhofer, Elmaghraby, and Morse (1959), Kesten and Morse (1959), and Wesler (1959). In the first, attention was given to the selection of the multinomial event with the highest probability. In two closely related papers, Rao (1957, 1958) considered maximum

likelihood estimation for the multinomial distribution. Johnson (1960) described properties and applications of an approximation to the multinomial distribution.

Additional References: Crow (1958); Johnson (1959); Mendenhall and Lehmann (1960); Ramasubban (1958, 1959).

Developments in Nonparametric Statistics

Although attention given to nonparametric statistics was somewhat less than during the previous three-year period, a substantial number of papers appeared.

General and Theoretical Papers

Arguing against the compulsive use of nonparametric methods in place of classical parametric methods and for retention of the latter, despite the failure of the scale of measurement to be interval in form, were Cox (1958c), Gaito (1959), and Kogan (1960). Believing that nonparametric techniques should serve as exploratory or screening devices, Gaito urged that they be given limited use; Kogan (1960) cited the more extensive utility of parametric methods, and also the strikingly "rapid potency of the central limit theorem." On the other hand, in a detailed and systematic paper concerning a distinction between approximate and exact methods in nonparametric statistics, Sawrey (1958) strongly implied the importance of properties of the scale of measurement in the decision of the appropriate use of an exact or approximate nonparametric test, as did Senders (1958) much more explicitly in her textbook.

Among the most important theoretical papers were those of Savage (1957), who for various trend hypotheses considered detailed relationships among the probabilities of rank order with implications for admissibility of rank-order tests; of Rao, Savage, and Sobel (1960), who took up the two-sample censored case; and of Savage (1960), who furnished rules for the computation of rank-order probabilities with particular reference to the determination of the efficiency of Wilcoxon's two-sample test relative to the standard-normal test and *t*-test.

Making use of order statistics and of only the assumption that continuity exists in the marginal distributions, Dunn (1959b) developed estimates of joint (bounded) confidence intervals for the medians of a bivariate population. For the case of two independent samples, Birnbaum and McCarty (1958) described a numerical procedure based on an extension of the Mann-Whitney formulation for determining how large a sample would have to be to yield a distribution-free one-sided confidence interval of given width and specified level. Previously Birnbaum and Klose (1957) had given bounds for the variance of the Mann-Whitney statistic. To determine nonparametric tolerance limits, Somerville (1958) furnished useful tables.

Theoretical papers concerned with the concepts of power and efficiency included that of Chernoff and Savage (1958), who, for two absolutely continuous cumulative distributions of two sequences of ordered observations, considered properties of asymptotic normality and efficiency of several nonparametric tests following a certain form and that of Fraser (1957), who, in making use of an invariance principle, derived what he termed to be the most powerful tests for ranked data relative to normal alternatives. Witting (1960) developed a generalized efficiency measure for nonparametric tests based on the Pitman approach.

Significance Tests

Articles concerned with new nonparametric tests or with modifications of existing ones were numerous. Without making an assumption of either continuity or independence, Kuang (1960) derived a probabilistic inequality that indicates whether two samples can be contained in a certain class of distributions. In an ingenious development, Tukey (1959) proposed an easy and quick test to determine whether or not two independent samples come from the same population. He proposed summing the number of values in the first group (designated as the sample with the largest scale value) that exceed all values in the second group and then adding to this frequency the number of values in the second group not reaching the smallest value of the first group. For a two-tail test the critical frequencies in the total count are 7, 10, and 13 at the 0.05, 0.01, and 0.001 levels. To facilitate the comparison of changes in an experimental group with those of a control group, Silverstein (1958) urged the use of existing nonparametric tests once the differences between measures (changes) have been ordered.

In an expository and historical paper, Darling (1957) discussed the Kolmogorov-Smirnov and Cramér-Von Mises tests from the standpoint of goodness-of-fit and comparison of two samples. Other contributions pertaining to the Kolmogorov-Smirnov statistic included papers by Carvalho (1959), who presented a new derivation of the distribution of the statistic; by David (1958), who developed an adaptation of the test for three samples; and by Kiefer (1959), who furnished *k*-sample analogues for both the Kolmogorov-Smirnov and the Cramér-Von Mises tests.

Much attention was given to tests for comparing independent samples. In an informative article Kruskal (1957) described in historical perspective five independent proposals that anticipated Wilcoxon's unpaired two-sample test. For testing the hypothesis that two independent populations are unlike only in location, Sukhatme (1958a) studied the asymptotic behavior of the Mann-Whitney *U* statistic. Subsequently, Sukhatme (1958b) furnished a new nonparametric test for comparing variances and described a formula for its asymptotic relative efficiency. Also noteworthy in the instance of two independent samples was Halperin's (1960) extension of the familiar tests of Wilcoxon and of Mann and Whitney for samples that are censored at

identical fixed points, and he developed significance tables for sample sizes less than or equal to eight and for several degrees of censoring.

Resembling a one-way analysis of variance procedure for the comparison of several treatments with a control group when the numbers of observation are all equal is the multiple-comparison rank-sum test proposed by Steel (1959a), who discussed both the exact and approximate distribution and presented an example as well as a tabulation of critical values. In a later paper Steel (1960) proposed and illustrated a multiple-comparison rank-sum test that permits the simultaneous comparison of all possible pairs of treatments in a one-way classification when the numbers of observation are equal for all treatments. In a similar vein, Wallace (1959c) furnished an improved beta approximation to the Kruskal-Wallace test for a one-way analysis of variance ranks.

For matched samples, several innovations on the sign test and signed-rank test appeared. With respect to the hypothesis that the medians of two not necessarily independent variables have a particular value, Blumen (1958) developed a new bivariate sign test. In the instance of Hodges's bivariate sign test, Klotz (1959) obtained the complete null distribution from n equal to 1 through 30. Of considerable help to researchers are the tables for the sign test prepared by Arthur Cohen (1959) that furnish maximum likelihood estimates of binomial parameters when the probabilities differ from one-half. Extending the two-sample sign test to k-variate distributions involving three or more matched samples, Wormleighton (1959) proposed a test statistic based on study of tests of permutation symmetry that with an asymptotic chi-square distribution contains more degrees of freedom than Friedman's test and offers sensitivity to a larger variety of alternatives. Related papers were those of Steel (1959b), who developed a multivariate sign test, and of Walsh (1959c), who presented an exact nonparametric model in the instance of randomized blocks.

With regard to the signed-rank test, Walsh (1959a) attempted to clarify certain recent misunderstanding concerning the equivalence of Wilcoxon's test to a subclass of some tests that he had proposed previously and went on to demonstrate that his nonequivalent results contain useful properties superior to the information furnished by Wilcoxon's procedures. For the Wilcoxon signed-rank procedure, Pratt (1959) described ways for handling zeros and ties.

Tests of Randomness

That the study of randomness constituted an area of major interest was apparent from several papers. Two closely related studies by Barton, David, and Mallows (1958) and by Barton and David (1958) treated application of Wilcoxon's and the rank-test statistics, respectively. The substantive aspect of the two papers is a paired comparison task concerned with a sequence of two alternatives, such as the requirement for a judge to rank in order of age the pictures of N_1 men and N_2 women when in actuality all

individuals are of the same age. Obviously the null hypothesis of randomness is appropriate to ascertain whether the existence of bias on the part of the experimenter to judge women to be of higher or lower age can be inferred.

Likewise Goodman (1958) proposed a simplified-runs test and likelihood-ratio test of randomness in a sequence of two or more alternatives that could be simplified to significance tests similar to those applied to determine independence in contingency tables. In a paper related to the problem handled by Hotelling's T^2 statistic, Chung and Fraser (1958) proposed several nonparametric randomization tests for the multivariate two-sample problem—on the doubtful assumption, however, of independence among the variables—and offered a method for simplifying computations in the instance of larger samples.

The Tau, Rho, and Other Nonparametric Coefficients of Association

The most important article concerning measures of association was that by Kruskal (1958), who, in emphasizing both the probabilistic and operational interpretations of population values in conjunction with rank measures of association for bivariate populations, discussed comprehensively the quandrant measure, Kandall's tau, and Spearman's rho. Kruskal described their interrelationships, as well as their connections with certain measures of association found in cross-classifications; surveyed underlying sampling theory; developed an informative historical frame of reference; and stated his preference for use of tau instead of rho. Having 25,000 sets of correlated random normal deviates available, Fieller, Hartley, and Pearson (1957) investigated and compared the sampling distributions of three measures of rank correlation—Spearman's rho, Kendall's tau, and the Fisher-Yates index.

Studying the rank analogues of the familiar product-moment partial correlation, Somers (1959) showed that the ordinary product-moment correlation coefficient, rho, and tau are specialized cases of a generalized coefficient. Taking Somers's paper as a point of departure, Goodman (1959) presented significance tests appropriate to a number of different partial correlation coefficients that are related to tau.

Hays (1960) set forth an alternative measure of concordance which, though parallel to Kendall's coefficient W, is a function of the average Kendall tau coefficient among all possible pairs of judges; he suggested a significance test of this concordance index. To measure association in a contingency table with ordered categories, Karon and Alexander (1958) proposed a modification in Kendall's tau coefficient. Easing the computational effort in calculation of tau is Griffin's (1958) simple graphic method.

For the calculation of an average Spearman rho correlation between rankings on a criterion measure and a set of m independently made rank-

ings corrected for ties, Cureton (1958) developed and illustrated a formula. In the instance of nominal scales, J. Cohen (1960) presented a coefficient of agreement.

Regression and Correlation

In correlation and regression theory, an important general theoretical paper was that by Kiefer and Wolfowitz (1959), who considered optimum experimental designs and computational procedures in regression problems of estimation and testing of hypotheses from the standpoint of several criteria. Box and Draper (1959) described a design for fitting a polynomial to a true function with minimum error over a specified region.

For the situation in which samples are taken from bivariate non-normal populations, Srivastava (1960) carried out a theoretical investigation of the sampling distribution of regression coefficients. Additional contributions to the distribution theory were those of Williams (1959), who presented an approximate significance test for the difference between two non-independent correlation coefficients; of Hooper (1958), who investigated asymptotic variances of canonical correlation coefficients with applications to cases of both zero-order and multiple-correlation coefficients; and of James (1960), who studied the distribution of the latent roots of the covariance matrix.

In two other theoretical papers on multivariate analysis, Pillai and Samson (1959) developed expressions for the moments of Hotelling's generalization of T^2, and Lawley (1959) obtained results pertaining to the approximate distribution of canonical correlation coefficients.

Estimation of Parameters

Making use of the theory of least squares in relation to problems concerning linear hypotheses in multivariate analysis, Rao (1959) furnished estimates of parameters as well as test criteria when the variances and covariances, though unknown, can be estimated. Since the distribution problems pose no particular difficulties, valid inferences can be made by means of reference to available significance tables of t and F. Nicholson (1957) concluded that no use should be made of incomplete multivariate samples in problems of prediction, although under certain circumstances all the observations in an incomplete sample can be used to construct improved estimators.

For two variables with a bivariate normal distribution, Olkin and Pratt (1958) developed unbiased estimates of certain correlation coefficients and included tables to facilitate the process. Replacing a least-squares estimate by one quickly determined, Barton and Casley (1958) pointed to the applicability of the latter index to certain topics of censored data and its

consistency under the condition of a structural, rather than a regressive, relationship between the dependent and independent variables.

In the instance of an exponential function, Finney (1958) described methods for estimation of a key parameter. In two particularly interesting papers based on economics research with implications for psychology, Quandt (1958, 1960) considered problems of estimating and testing hypotheses about parameters in a linear-regression system when, at a certain value for the independent variable, such as time, there is a suspected switch in the trend of the relationship.

For the situation in which two regression lines intersect, Kastenbaum (1959) furnished a confidence interval. The construction of confidence intervals with respect to arbitary real functions of multiple correlation coefficients was the subject of a note by Mandel (1958). Roy and Gnanadesikan (1957) also devoted efforts to finding multivariate confidence bounds.

Serial Correlation

There was less interest in problems of serial correlation than during the previous three years. Weinstein (1958) considered various definitions of the serial-correlation coefficient relative to the estimation of autoregressive parameters from a short time series, and, in terms of his examination of estimates obtained from three experimental series, concluded that the estimates are less influenced by changes in definition of serial correlation than by differences in basic method of estimation. He then introduced a new definition of the serial correlation. Siddiqui (1958) studied the distribution of a serial correlation, and McGregor (1960) proposed an approximation test for serial correlation in polynomial regression.

Regression Analysis and Prediction

A variety of problems was studied in the area of regression analysis and prediction. In the prediction of a continuous dependent variable from several independent variables (some of which are assigned dummy values corresponding to membership classifications as in a nominal scale), Suits (1957) described restraints that must be imposed upon the parameters of the regression equation in order that determinate estimates can be obtained. Cox (1958b) described methods of regression analysis for instances in which the dependent variable can assume only two values such as 0 and 1; subsequently he (1958d) extended application of his model to the analysis of two-by-two contingency tables involving matched pairs and to testing the extent of agreement between a binary sequence of observed values and a corresponding sequence of probabilities.

For treatment of certain types of experimental data, Williams (1958)

described how simultaneous regression equations could be employed, and expressed a preference for their use to use of the discriminant function. In estimating the regression coefficient of y on x, Cox (1960) showed how increased precision can be realized when prior information on a supplementary variable to which y and x are related is available. In a similar vein, Seal (1959) furnished and illustrated a model for a sampling plan that permits the obtaining of measures on an expensive variable from knowledge furnished by an inexpensive auxiliary variable with which the former variable is highly correlated.

Two contributions in regression analysis of particular interest to psychologists appeared. In their expository treatment of path analysis, Turner and Stevens (1959) used simple diagrams to explain the conceptual nature of cause and effect in regression analysis as well as to describe properties of feedback and homeostasis. In a critical discussion of their paper, Wright (1960) advocated the systematic substitution in path analysis of what he considered dimensionless path coefficients by corresponding concrete path regressions. The problem of covariance was the subject of the second important paper, in which Lord (1960) in the instance of large samples, presented formulas to allow for the fallibility of measures in the control variable—a circumstance that is particularly pertinent to many investigations in education and psychology.

How to select a limited number of predictor variables from a larger set in regression analysis was the central problem of three papers. Comparing both theoretically and numerically the Doolittle, the Wherry-Doolittle, and the Summerfield-Lubin methods of multiple correlation, Anderson and Fruchter (1960) demonstrated the equivalence of the latter two in selecting the same set of predictors in the same order and recommended the use of the Summerfield-Lubin formulation as the best least-squares procedure in view of its computational ease, compactness, and clarity of interpretation of interim values. Making use of the expected value of the size of a confidence interval over all possible regression samples and over all possible sets of predictors as a basic criterion for the precision of a selected set of predictor variables, Linhart (1960a) furnished and illustrated his method for determining which set of r variables out of k available randomly distributed ones should be chosen. In a related paper, Linhart (1960b) subsequently evaluated criticisms concerning the choice of a measure of predictive precision in regression analysis, and referred particularly to use of the expected value $E(1)$ of a confidence interval of width 1 for the variable to be predicted.

Computational and Graphic Aids

Allied to the three papers just cited were several others helpful in simplifying or reducing computational labor in regression analysis. The table prepared by Steck (1958) for computing trivariate probabilities has long

been needed. Greenberg and Sarhan (1959) discussed applications of matrix inversion in the analysis of correlational data. To obtain higher-order regression coefficients, Cowden (1958) described analogues to a method by which higher-order partial correlation coefficients are calculated from those of a lower order. Foote (1958) presented a simple desk-calculator method of obtaining multiple and partial correlation and regression coefficients that involves no back solution. In the analysis of several numbers of measures on the same individuals, Schutz (1960) presented a labor-saving technique that he referred to as the "little jiffy correlator."

For the determination of a multiple correlation coefficient $R_{1.23}$, Waugh and Fox (1957) demonstrated a graphical method, and, in the instance of moving averages and adjustments in time series, Mincer (1957) showed how a graphical approach could be employed.

Curve Fitting

Contrary to the oversimplified impression conveyed by most textbooks, the fitting of a linear-regression equation customarily rests on the assumption of fixed, or error-free, values in the independent variables. That the fitting of a regression line is not a simple and mechanical process has been clearly set forth in a definitive and penetrating article by Madansky (1959), who considered the implications of presence of error in both the independent and dependent variables. He surveyed and evaluated solutions for determining consistent estimates of slope and intercept of regression lines from samples of paired observations when various assumptions regarding the properties of error and when various types of information are available for constructing consistent estimates. Pertinent to the problems just posed are the contents of the previously cited paper by Barton and Casley (1958), who furnished improved though rapid estimates of regression coefficients. On the other hand, in choosing to ignore the presence of error in the independent variable but to allow error in the dependent variable to be randomly distributed, David and Arens (1959) proposed criteria for spacing a given set of paired observations to achieve an optimal straight line. After pointing out that the true line may vary from experiment to experiment when a sequence of observations is taken over the same set of values on the predictor variable because of the presence of uncontrolled factors from one set of runs to another, Scheffé (1958) furnished a mathematical model for fitting the line relative to the hypotheses of equality of slopes of the true lines or an identity of the true lines.

For certain types of cumulative data in which the error of successive observations may not be independent, Mandel (1957) described two models for both independent and cumulative data and through them showed that the frequently used least-square estimates of independent error derived from the first model are not applicable to cumulative data conforming to the second model. In order to achieve a smoothing of probability-density functions, Whittle (1958) developed an equation that determines an op-

timal-weighting function. Citing certain pedagogical advantages, Karst (1958) described a method of linear curve fitting by means of which the sum of the absolute values of vertical discrepancies of points to the line is a minimum. Wagner (1959), also rejecting the least-squares approach, suggested two alternative criteria in linear-programing techniques for regression analysis. Askovitz (1959) presented short-cut techniques embodying centroids of sets of points that could be utilized in least-square applications of line fitting and in the determination of the mean of a frequency distribution.

Miscellaneous Articles

Making use of a table of random numbers, Hoffman (1959) described a procedure for constructing pairs of variables so that their correlation will be equal to any specified predetermined magnitude. For N distributions of variates, each based on the same population, Willis (1959) derived lower-bound formulas for the mean intercorrelation coefficient.

Representing a substitute for Fisher's well-known z conversion procedure, Nair's transformation of a correlation coefficient was studied by Sankaran (1958), who concluded that a corresponding inverse-sine transformation of this new coefficient in several situations is as satisfactory as Fisher's transformed coefficient. After introducing a family of modifications to Fisher's transformation of a correlation coefficient, Laubscher (1959) was able to show that within the family Fisher's form of the transformation is optimum.

Additional References: Finney (1960); Guttman and Guttman (1959); Ostle and Steck (1959); Rao (1958); Schaie (1958); Williams (1959a); Wright, Manning, and DuBois (1959).

Factor Analysis

Some of the problems involving communality estimation, rotation, and factorial invariance were clarified, and reformulations of the factor problem were offered. More researchers in education and psychology than previously used factor-analytic techniques. This section covers the most important methodological studies.

Communality Estimation and the Number of Common Factors

The problems of communality estimation and the number of factors to extract are inherently related, since estimation of the communality is made in order to define the common factor space. It can be safely stated that no solution for the communality problem has been found—and indications are that under the classical formulation of the problem none will be found.

Thus it is only natural that factor analysts turn toward redefining the concept of communality or toward attempting to determine the conditions under which prevailing attitudes do not seriously affect the psychological interpretations of factor structures.

Criticisms of the current factor theory are based on the following reasons: (a) formulation of the communality problem on the basis of minimal rank of the correlation matrix (Cattell, 1958; Guttman, 1958a; Wrigley, 1957a, 1959); (b) *a priori* acceptance of Thurstone's idea of parsimony (Guttman, 1958a, b); (c) definition of the term *communality* (Wrigley, 1957b); and (d) failure to take into account the stochastic properties of the measures used and their effect upon the final factorial structure (Wrigley, 1959).

In the use of communality estimates, Guttman's classic lower bound as given by the squared-multiple correlation between one variable and the $n - 1$ remaining variables seems to be firmly entrenched (Cattell, 1958; Tryon, 1957a; Wrigley, 1957a, b, 1958, 1959). After reviewing the communality formulations of Spearman, Thurstone, Guttman, and Tryon, Wrigley (1957b) stated that the squared-multiple correlation coefficient as an estimate of the communality in many ways overcomes the previous problems of communality estimation, because there are no alternative sets of diagonal values; the squared-multiple coefficient is probably less influenced by sample size (thus overcoming some objections to stochastic approaches), since values calculated from larger samples may be higher or lower. Thus the problem of determining the communality becomes separate from that of determining the number of factors. Wrigley pointed out the disadvantage of the lack of a test of significance, but left the solution of this problem to the statisticians. He also indicated the use of the squared-multiple correlation as an initial estimation of the communality in order to reduce the time involved when using Lawley's maximum-likelihood methods (Wrigley, 1958) and its correction by subtracting from such a diagonal value the mean of the rejected latent roots. Although Wrigley had stated that such use of the squared-multiple correlation produces good results, he pointed out that the communality might converge to an unlikely value, and that, since the communality based upon maximum likelihood depends on the size of the sample of persons, the twin decisions of communalities and the number of factors is confounded.

Wrigley (1959) also attempted to approach the communality problem as a function of the number of factors being extracted. His results indicated irregular increases in the communality as more factors were postulated. Moreover, while using Guttman's lower bound as an initial estimate, he found that some communalities eventually became greater than unity. The rate of convergence of the communality estimates appeared fastest when a small number of factors was hypothesized. In some cases the values had not converged after 80 iterations. His study also indicated that the last value obtained for the communality was a function of the initial communality estimate.

Approaching the problem of common-factor space from a different angle, Cattell (1958) called for the clarification of error factors and real factors, population factors and sample factors. Thus the problem is not reduced to attaining minimal rank nor to finding the standard error of a factor loading. In the process of separating real and error factors Cattell suggested that initial estimates of the communalities be based on the squared-multiple correlation and that concern be given to reproduction of the off-diagonal elements of the correlation matrix.

Guttman (1958a, b) criticized the desire that factorial research be based on the Thurstonian concept of parsimony, citing that all evidence which has been collected by methods outlined by Thurstone points toward negation of this idea. Guttman disproved that the rank of a correlation matrix may always be reduced to the smallest integer greater than $\frac{1}{2}(2n + 1 - \sqrt{8n - 1})$, but rather that the best possible upper bound is $n - 1$. He also postulated that for a simplex the rank can never be less than $n - 2$, but DuBois (1960) succeeded in providing an example in which Guttman's contention is not upheld. Further evidence by Kaiser (1960a) indicated that the alpha-reliability of a factor is depressed when communality estimates are made and when the number of factors extracted is small. In this light Kaiser suggested use of unities in the diagonals, a principal-axis solution using all factors having latent roots greater than one (1960b).

An attack upon the communality problem through a redefinition and generalization of the common-factor theory was proposed by Tryon (1957a, b, 1958a, b, 1959). Under his reformulation, Tryon (1957a) maintained that his three definitions lead to "precise" formulas for the determination of the communality (a) from the k necessary and sufficient dimensions derived by iterative factoring, (b) from the $n - 1$ remaining variable-domains, and (c) from the k' multiple clusters of the n variables. Kaiser (1959b), however, pointed out that convergence necessary under Tryon's formulation cannot always be reached with empirical matrices; in fact the solution for communalities converges if and only if the matrix has unique minimum-rank communalities. For clarification of the numerous cluster-analysis techniques, key-cluster analysis, total communality, cumulative communality, preclustered cumulative communality, and rational cumulative communality, the reader is referred to Tryon (1959).

Tyler and Michael (1958) reported an empirical investigation concerning the problem of communality estimation and concluded that for the matrix under study there appears to be no loss of psychological meaningfulness when either estimates of communalities determined iteratively or unities are used. Cattell (1958) also suggested the decreasing importance of the exact value of the communality from the empirical point of view if correlation matrices are large, when he indicated that the diagonal elements are only $1/n$th the number of elements in the matrix. However, Cattell indicated that the use of ones in the diagonal is unscientific, since it does not permit the separation of error factors from the common factors. An excellent review of the communality problem, its problems and meaning,

can be found in Dickman's (1960) dissertation, where a clear distinction is made between matrix, domain, and population-factor analysis.

For the researcher seeking to solve the problem of what should be placed into the diagonals, no exact answer can be given. Indications are that the insertion of Guttman's lower-bound value, the squared-multiple correlation, and the use of principal components having positive latent roots is the most reasonable and scientific approach at this time.

Rotation

During the last three years the formulation of one of the most adequate solutions to the problem of orthogonal analytic rotation has occurred. Unfortunately, the oblique case, although studied with much vigor, has not as yet provided researchers with a fully acceptable criterion despite Carroll's (1957) important advance.

The major significant breakthrough in the orthogonal case was given by Kaiser (1958) with his varimax criterion. The varimax criterion maximizes the variance of the squared elements by columns after each test has been corrected for uniqueness. (The correction is removed after rotation is completed.) Kaiser pointed out that not only is Thurstone's criterion of simple structure attained, but also the more important characteristic of factorial invariance is realized. Indications are that the varimax criterion has become well accepted by researchers using factor analytic techniques (Comrey, 1959; Dickman, 1960). Since the criterion to be maximized has been outlined for purposes of computer programing (Kaiser, 1959a), it should be made part of a basic computer library for those engaged in factor analyses (Kaiser, 1960b). Although Kaiser also generalized the varimax criterion to the oblique case (covarimin), indications are that it is biased in that the factors seem to approach a position tending toward orthogonality (Carroll, 1958).

After reviewing the problems involved with the analytic criterion as defined by his original quartimin and Kaiser's covarimin, Carroll (1958) proposed that a combination of these two criteria be used, for the quartimin produced an opposite bias to that of the covarimin criterion. Since the first term of Kaiser's covarimin function is the same as the complete quartimin function, Carroll proposed subtracting one-half the product of the sums of squared loadings from the covariance term. This new criterion for rotation is called biquartimin. Although it has been reported that the biquartimin has been very successful on Thurstone's box problem (Dickman, 1960), it has been suggested that the split between quartimin and covarimin is not equal and that, when the data are more complex, a larger part of the covarimin function is required. The biquartimin criterion requires that the sum of cross-products of squared factor loadings are minimized along with the sum of cross-products of deviations of squared factor loadings from their mean value.

After reviewing the inadequacies of previous analytic criteria (Carroll's quartimin as being too nearly oblique, Kaiser's covarimin as too nearly orthogonal) and pointing to the necessity for a variation in the proportion of combined criteria which change with the complexity of the tests, Kaiser and Dickman (1959) provided a new solution to the oblique case called binormamin in which the simplicity coefficient, or value determining the combinations of the covarimin and quartimin, varies as a function of the simplicity of the structure under study. The new approach uses the normalization step which has proved so successful in the varimax criterion. In effect, binormamin minimizes the sum of the cross-products of squared loadings normalized by rows and columns over all pairs of factors. The authors reported that binormamin is also subject to a bias which appears to be a function of the complexity of the tests. The bias is considered to be essentially nonexistent when data are cleanly structured but to be distinct for problems containing factorially complex variables.

Cattell and Muerle (1960) severely criticized present rotational criteria as constituting entirely the wrong functions to be maximized or minimized. Cattell stated that both simple structure and orthogonality are incompatible except in rare cases and that orthogonality is of little use for scientific work. Cattell proposed that the hyperplane count be maximized, that is, the number of near-zeros in the factor columns. Essentially Cattell proposed a compromise between subjectivity and mathematical rigidity.

With the advent of numerous analytic criteria for rotation and a greater stress upon psychological meaningfulness, a number of studies have been conducted to compare and to evaluate the effectiveness of each method. Wrigley, Saunders, and Neuhaus (1958) compared the quartimax rotation of the centroid factor loadings for Thurstone's *Primary Mental Abilities Test Battery* with the Thurstone simple structure method, Zimmerman's revised simple structure, Holzinger and Harman's bifactor analysis, and Eysenck's group factor analysis. The evidence indicated that the quartimax results agree very closely with Holzinger and Harman's and Eysenck's solutions and only moderately well with the two simple structure solutions. The authors pointed out further that, in terms of parsimony, the advantage seems to be with quartimax but that, in terms of factorial invariance, the varimax solution is much superior. Further study is required.

Kaiser (1960d) conducted a similar study of analytic rotations excluding both the Holzinger and Harman method and the Eysenck method from the comparison. Results indicated that psychologically there appeared to be no difference in the rotated solutions. However, it was emphasized that the merit of the varimax lies not in the observed similarities, but rather in the fact that the varimax is based on a scientifically more fundamental and more important criterion—factorial invariance. Further study with the varimax criterion was made by Comrey (1959) using data from the *Minnesota Multiphasic Personality Inventory*. Comrey reported that the varimax in general is more satisfactory than Thurstone's method and that, if a choice is available, the varimax rotation should be preferred. He also

suggested that it be used prior to oblique rotation when factor plots are to be made.

Of interest to those who do not have available electronic computers is the study by Fruchter and Novak (1958) who compared the 2 x 2 graphical method, Thurstone's analytic method, and a "direct rotational" method devised by Harris. Using as their criterion the principle of simple structure, the authors found that the graphical method is superior, but that the direct rotational method is the most economical of the researcher's time. Further work with the rotational method devised by Thurstone has been conducted by Sokal (1958). Sokal found Thurstone's results unsatisfactory because in some circumstances a given trial vector would not yield a reference vector with a well-defined hyperplane. This occurred because of the problem of collinear vectors, which makes it impossible to assure the correct selection of a reference vector for purposes of simple structure. Sokal's modification, which is restricted to calculation by electronic computers, considers all the variables simultaneously.

Working from the Gram-Schmidt method of establishing an orthonormal basis, Cureton (1959) adapted this useful mathematical technique to determine a transformation matrix that will rotate factors so that one of the new axes may be placed in a predetermined position. Such a technique may prove useful when a battery of tests includes "marker" variables.

In summary it may be stated that, for the orthogonal case, the normal varimax criterion appears to be in greater use than other orthogonal procedures. Unfortunately, since generalization to the oblique case has only been made by attempting compromises with previous orthogonal criteria, a definitive criterion is yet to be found. Electronic computers are an absolute necessity if current trends in analytic rotation continue.

The Common-Factor Problem

Increased use of factor analytic techniques has brought about the necessity for the comparison of factors among different studies. For the case involving different but not parallel tests for the same group, Tucker (1958) proposed the "interbattery" method of factor analysis. Tucker's procedure utilizes the correlation matrix between batteries of tests in determining the common factors rather than the more conventional manner of analyzing the factor structure of the correlations within batteries. The result permits consideration of those factors which are common only to both batteries. Although Tucker pointed out that this method requires no estimate of the communalities, Gibson (1960) has shown that, since certain assumptions made by Tucker may not hold, the communality problem must be faced. The Tucker method provides a statistical test for the minimum number of factors involved and for the calculation of the correlations between corresponding factors. Gibson (1960) pointed out that Tucker's method assumes that the vector configuration of the two tests within the factor space of overlap contains two sets of principal axes in the same location and also

assumes that their associated latent roots are identical. Gibson suggested that the problem can be overcome by selection of such test batteries that there exists a parallelism between sub-batteries so that their sums of squared loadings on a factor cannot be too different from any other factor. Gibson demonstrated that failure to create such a condition may lead to imaginary factor loadings.

General Computational Procedures

Wherry (1959) outlined a method of obtaining hierarchical factor solutions without the necessity for rotation. Instead of factoring and rotating the factor structure at each stage, inverting and normalizing the reference vector correlation matrix, and then refactoring, the Wherry method, which begins with the multiple group method of factoring, assumes that, if all overlap is removed from the clusters, they will have simple structure with respect to each other. In a short paper Wolins (1959) presented a modification of the Wherry-Winer method for factoring large numbers of test items. The new method appears much easier to use in conjunction with tetrachoric correlations.

Using the principle of maximum likelihood for the estimation of factor loadings when certain loadings are assumed *a priori* to be zero, Lawley (1958) concluded that factor loadings can be calculated under such an assumption for both the orthogonal and oblique cases. Lawley showed that for various hypotheses it is possible to solve numerically the maximum likelihood equations of estimation, but that the amount of work with matrices of even small order necessitates the use of an electronic computer.

Guttman (1959) pointed out that analysis of correlation matrices by factor analytic techniques is justified stochastically only if the regressions are linear, and he has shown that in general one set of new scores, at most, can be found to maintain the observed rank orders. Guttman posed and answered the following two questions: Can real numbers be assigned to given qualitative categories for a given population in such a way that the resulting numerical variables will have linear regressions on each other? If so, in how many ways can this be done, and what are they? He also pointed out that, if the question cannot be answered, nonlinear theories of scale analysis, latent structure analysis, or facet analysis are in order. In another paper Guttman (1957) presented empirical evidence of correlation matrices that conform to his radex theory. Two lists are cited, one representing approximate simplexes and the other approximate circumplexes. Fruchter and Fleishman (1957) reported a study in which they attempted to determine whether the presence of spuriously high intercorrelations among experimentally dependent variables distorts the common-factor structure of a battery. Results showed that the structure of the common factors is not greatly affected.

In an excellent article contrasting factor analysis and cluster analysis,

Tryon (1958b) described the method and theory underlying both "*v*-analysis" and "*o*-analysis." The "*v*-analysis" is concerned with grouping a minimal set of behavioral properties that are most independent and best predict the scores of the subjects. The "*o*-analysis" is a procedure for locating and conceptualizing types of objects or persons.

Madansky (1960) presented extensions of existing determinant methods for the solution of accounting equations in latent class analysis. McHugh (1958) also published a short paper outlining corrections of some of his earlier work on latent class analysis. He pointed out where stronger statements can be made about identifiability of structural parameters.

Gibson (1959) set forth an excellent outline of the theoretical formulations relating factor analysis, latent structure analysis, and latent profile analysis, and he attempted to show how the latter two models avoid the difficult problems of communality estimation, rotation, and curvilinearity that plague conventional factor analyses. Limitations of the latent profile analysis were pointed out as being: (a) lack of a scale of measurement for the latent continuum and (b) definition of the number of necessary latent dimensions since as many as $q - 1$ dimensions would be required, where q is the number of latent classes.

Maxwell (1959) recently outlined a number of statistical tests which he considers ought to be used by factor analysts, in view of the fact that factor analysis lacks the sophistication of classical statistical methods in not having such information as the standard error of a factor loading. Significance tests for an entire correlation matrix, for the comparison of two variance or covariance matrices, and for residual matrices were given.

Hotelling (1957) explained that in many instances certain statistical procedures, such as regression analysis, multiple correlation, and multivariate analysis of variance, are more appropriate techniques than factor analysis. In attacking the problem of dimensionality of a continuous multivariate population, Hotelling pointed out that the rank is equal to that of the sample under certain conditions, provided the number of degrees of freedom among subjects is greater than the number of variables. However, when the observed score is considered to be made up of a real part and a random error, dimensionality can only be ascertained by obtaining estimates of the errors by suitable replications and the use of multivariate analysis rather than by factor analysis. Hotelling also suggested a method for comparing covariance matrices using the characteristic equation and distributions of the latent roots.

Additional References: Other references of general interest, which are worthy of reading particularly by those interested in empirical examples or by those who are only beginning their study of factor analysis, include the contributions of Bernyer (1957); Borgatta (1958-59); Dingman (1958); DuBois and Manning (1959); French (1959); Garside (1958); Kline (1959); Michael (1958); and Royce (1958). Somewhat more mathematically oriented articles are those of Baggaley (1960); Bernyer (1958); Demaree (1957); Hamilton (1958); Tucker (1958).

Bibliography

AGGARWAL, OM P. "I. Bayes and Minimax Procedures in Sampling from Finite and Infinite Populations." *Annals of Mathematical Statistics* 30: 206-18; March 1959.

AGGARWAL, OM P., and GUTTMAN, IRWIN. "Truncation and Tests of Hypotheses." *Annals of Mathematical Statistics* 30: 230-38; March 1959.

AITCHISON, J., and SILVEY, S. D. "Maximum-Likelihood Estimation of Parameters Subject to Restraints." *Annals of Mathematical Statistics* 29: 813-28; September 1958.

AITCHISON, J., and SILVEY, S. D. "Maximum-Likelihood Estimation Procedures and Associated Tests of Significance." *Journal of the Royal Statistical Society* (Series B, Methodological) 22: 154-71; No. 1, 1960.

ANDERSON, HARRY E., JR., and FRUCHTER, BENJAMIN. "Some Multiple Correlation and Predictor Selection Methods." *Psychometrika* 25: 59-76; March 1960.

ANDERSON, R. L. "Use of Contingency Tables in the Analysis of Consumer Preference Studies." *Biometrics* 15: 582-90; December 1959.

ANDERSON, THEODORE W. *An Introduction to Multivariate Statistical Analysis.* New York: John Wiley & Sons, 1958. 374 p.

ANSCOMBE, F. J. "Dependence of the Fiducial Argument on the Sampling Rule." *Biometrika* 44: 464-69; December 1957.

ANSCOMBE, F. J., and GUTTMAN, IRWIN. "Rejection of Outliers." *Technometrics* 2: 123-47; May 1960.

ARMITAGE, P. "Numerical Studies in the Sequential Estimation of a Binomial Parameter." *Biometrika* 45: 1-15; June 1958.

ARROW, KENNETH J.; KARLIN, SAMUEL; and SUPPES, PATRICK, editors. *Mathematical Methods in the Social Sciences.* Stanford, Calif.: Stanford University Press, 1959. 365 p.

ASKOVITZ, SAMUEL I. "Graphic Methods Based upon Properties of Advancing Centroids." *Journal of the American Statistical Association* 54: 668-73; September 1959.

ATTNEAVE, FRED. *Applications of Information Theory to Psychology: A Summary of Basic Concepts, Methods, and Results.* New York: Henry Holt & Co., 1959. 120 p.

BAHADUR, R. R. "On Unbiased Estimates of Uniformly Minimum Variance." *Sankhyā* 18: 211-24; September 1957.

BAHADUR, R. R. "Some Approximations to the Binomial Distribution Function." *Annals of Mathematical Statistics* 31: 43-54; March 1960.

BAKER, GEORGE A. "Empiric Investigation of a Test of Homogeneity for Populations Composed of Normal Distributions." *Journal of the American Statistical Association* 53: 551-57; June 1958.

BANERJEE, SAIBAL KUMAR. "Expressions for the Lower Bound to Confidence Coefficients." *Sankhyā* 21: 127-40; March 1959.

BARRACLOUGH, ELIZABETH D., and PAGE, E. S. "Tables for Wald Tests for the Mean of a Normal Distribution." *Biometrika* 46: 169-77; June 1959.

BARTHOLOMEW, D. J. "A Test of Homogeneity for Ordered Alternatives." *Biometrika* 46: 36-48; June 1959. (a)

BARTHOLOMEW, D. J. "II. A Test of Homogeneity for Ordered Alternatives." *Biometrika* 46: 328-35; December 1959. (b)

BARTON, D. E., and CASLEY, D. J. "A Quick Estimate of the Regression Coefficient." *Biometrika* 45: 431-35; December 1958.

BARTON, D. E., and DAVID, F. N. "Non-Randomness in a Sequence of Two Alternatives: II. Runs Test." *Biometrika* 45: 253-56; June 1958.

BARTON, D. E.; DAVID, F. N.; and MALLOWS, C. L. "Non-Randomness in a Sequence of Two Alternatives: I. Wilcoxon's and Allied Test Statistics." *Biometrika* 45: 166-80; June 1958.

BASU, D. "On Sampling With and Without Replacement." *Sankhyā* 20: 287-94; December 1958.

BEALE, E. M. L. "Confidence Regions in Non-Linear Estimation." *Journal of the Royal Statistical Society* (Series B, Methodological) 22: 41-88; No. 1, 1960.

BECHHOFER, ROBERT E.; ELMAGHRABY, SALAH; and MORSE, NORMAN. "A Single-Sample Multiple-Decision Procedure for Selecting the Multinomial Event Which Has the Highest Probability." *Annals of Mathematical Statistics* 30: 102-19; March 1959.

BERKSON, JOSEPH. "Tables for Use in Estimating the Normal Distribution Function by Normit Analysis." *Biometrika* 44: 411-35; December 1957.

BERKSON, JOSEPH. "Nomograms for Fitting the Logistic Function by Maximum Likelihood." *Biometrika* 47: 121-41; June 1960.

BIRNBAUM, Z. W., and KLOSE, ORVAL M. "Bounds for the Variance of the Mann-Whitney Statistic." *Annals of Mathematical Statistics* 28: 933-45; December 1957.

BIRNBAUM, Z. W., and MCCARTY, R. C. "A Distribution-Free Upper Confidence Bound for Pr $\{Y<X\}$ Based on Independent Samples of X and Y." *Annals of Mathematical Statistics* 29: 558-62; June 1958.

BLALOCK, H. M., JR. "Probabilistic Interpretations for the Mean Square Contingency." *Journal of the American Statistical Association* 53: 102-105; March 1958.

BLOMMERS, PAUL, and LINDQUIST, E. F. *Elementary Statistical Methods in Psychology and Education.* Boston: Houghton Mifflin Co., 1960. 528 p.

BLUMEN, ISADORE. "A New Bivariate Sign Test." *Journal of the American Statistical Association* 53: 448-56; June 1958.

BLYTH, COLIN R. "Note on Relative Efficiency of Tests." *Annals of Mathematical Statistics* 29: 898-903; September 1958.

BODMER, W. F. "A Significantly Extreme Deviate in Data with a Non-Significant Heterogeneity Chi Square." *Biometrics* 15: 538-42; December 1959.

BONEAU, C. ALAN. "The Effects of Violations of Assumptions Underlying the *t* Test." *Psychological Bulletin* 57: 49-64; January 1960.

BOSE, R. C., and GUPTA, SHANTI S. "Moments of Order Statistics from a Normal Population." *Biometrika* 46: 433-40; December 1959.

BOX, GEORGE E. P., and DRAPER, NORMAN R. "A Basis for the Selection of a Response Surface Design." *Journal of the American Statistical Association* 54: 622-54; September 1959.

BUEHLER, ROBERT J. "Confidence Intervals for the Product of Two Binomial Parameters." *Journal of the American Statistical Association* 52: 482-93; December 1957.

BUEHLER, ROBERT J. "Some Validity Criteria for Statistical Inferences." *Annals of Mathematical Statistics* 30: 845-63; December 1959.

BULMER, M. G. "Confirming Statistical Hypotheses." *Journal of the Royal Statistical Society* (Series B, Methodological) 19: 125-32; No. 1, 1957.

BURKHOLDER, D. L. "On the Existence of a Best Approximation of One Distribution Function by Another of a Given Type." *Annals of Mathematical Statistics* 30: 738-42; September 1959.

CARROLL, JOHN B. "Biquartimin Criterion for Rotation to Oblique Simple Structure in Factor Analysis." *Science* 126: 1114-15; November 1957.

CARROLL, JOHN B. "Solution of the Oblimin Criterion for Oblique Rotation in Factor Analysis." Unpublished manuscript. 1958. 9 p.

CARVALHO, PEDRO EGYDIO DEOLIVEIRA. "On the Distribution of the Kolmogorov-Smirnov D-Statistic." *Annals of Mathematical Statistics* 30: 173-76; March 1959.

CATTELL, RAYMOND B. "Extracting the Correct Number of Factors in Factor Analysis." *Educational and Psychological Measurement* 18: 791-838; Winter 1958.

CATTELL, RAYMOND B., and MUERLE, JOHN L. "The 'Maxplane' Program for Factor Rotation to Oblique Simple Structure." *Educational and Psychological Measurement* 20: 569-90; Autumn 1960.

CHAKRAVARTI, I. M., and RAO, C. RADHAKRISHNA. "Tables for Some Small Sample Tests of Significance for Poisson Distributions and 2 x 3 Contingency Tables." *Sankhyā* 21: 315-26; August 1959.

CHANDLER, ROBERT E. "The Statistical Concepts of Confidence and Significance." *Psychological Bulletin* 54: 429-30; September 1957.

CHAPMAN, DOUGLAS G. "A Comparative Study of Several One-Sided Goodness-of-Fit Tests." *Annals of Mathematical Statistics* 29: 655-74; September 1958.

CHASSAN, J. B. "On the Development of Clinical Statistical Systems for Psychiatry." *Biometrics* 15: 396-404; September 1959.

CHASSAN, J. B. "On a Test for Order." *Biometrics* 16: 119-21; March 1960.

CHERNOFF, HERMAN, and MOSES, LINCOLN E. *Elementary Decision Theory.* New York: John Wiley & Sons, 1959. 364 p.

CHERNOFF, HERMAN, and SAVAGE, I. RICHARD. "Asymptotic Normality and Efficiency of Certain Nonparametric Test Statistics." *Annals of Mathematical Statistics* 29: 972-94; December 1958.

CHUNG, JAMES H., and FRASER, DONALD A. S. "Randomization Tests for a Multivariate Two-Sample Problem." *Journal of the American Statistical Association* 53: 729-35; September 1958.

CHURCHMAN, C. WEST, and RATOOSH, PHILBURN. *Measurement: Definitions and Theories.* New York: John Wiley & Sons, 1959. 274 p.

CLARK, FRANK EUGENE. "Truncation To Meet Requirements on Means." *Journal of the American Statistical Association* 52: 527-36; December 1957.

CLUNIES-ROSS, C. W. "Interval Estimation for the Parameter of a Binomial Distribution." *Biometrika* 45: 275-79; June 1958.

COCHRAN, WILLIAM G., and COX, GERTRUDE M. *Experimental Designs.* Second edition. New York: John Wiley & Sons, 1957. 611 p.

COHEN, A. CLIFFORD, JR. "Simplified Estimators for the Normal Distribution When Samples are Singly Censored or Truncated." *Technometrics* 1: 217-37; August 1959.

COHEN, A. CLIFFORD, JR. "Estimating the Parameter in a Conditional Poisson Distribution." *Biometrics* 16: 203-11; June 1960. (a)

COHEN, A. CLIFFORD, JR. "Estimating the Parameters of a Modified Poisson Distribution." *Journal of the American Statistical Association* 55: 139-43; March 1960. (b)

COHEN, A. CLIFFORD, JR. "Estimation in the Truncated Poisson Distribution when Zeroes and Some Ones are Missing." *Journal of the American Statistical Association* 55: 342-48; June 1960. (c)

COHEN, A. CLIFFORD, JR. "Misclassified Data from a Binomial Population." *Technometrics* 2: 109-13; February 1960. (d)

COHEN, ARTHUR. "Tables for the Sign Test When Observations Are Estimates of Binomial Parameters." *Journal of the American Statistical Association* 54: 784-93; December 1959.

COHEN, JACOB. "A Coefficient of Agreement for Nominal Scales." *Educational and Psychological Measurement* 20: 37-46; Spring 1960.

COLTON, THEODORE. "A Test Procedure with a Sample from a Normal Population When an Upper Bound to the Standard Deviation Is Known." *Journal of the American Statistical Association* 55: 94-104; March 1960.

COMREY, ANDREW L. "Comparison of Two Analytic Rotation Procedures." *Psychological Reports* 5: 201-209; June 1959.

COWDEN, DUDLEY J. "A Procedure for Computing Regression Coefficients." *Journal of the American Statistical Association* 53: 144-50; March 1958.

COX, DANIEL R. *Planning of Experiments.* New York: John Wiley & Sons, 1958. 308 p. (a)

COX, DANIEL R. "The Regression Analysis of Binary Sequences." *Journal of the Royal Statistical Society* (Series B, Methodological) 20: 215-42; No. 2, 1958. (b)

COX, DANIEL R. "Some Problems Connected with Statistical Inference." *Annals of Mathematical Statistics* 29: 357-72; June 1958. (c)

COX, DANIEL R. "Two Further Applications of a Model for Binary Regression." *Biometrika* 45: 562-65; December 1958. (d)

COX, DANIEL R. "Regression Analysis When There Is Prior Information About Supplementary Variables." *Journal of the Royal Statistical Society* (Series B, Methodological) 22: 172-76; No. 1, 1960.

CROW, EDWIN L., and GARDNER, ROBERT S. "Confidence Intervals for the Expectation of a Poisson Variable." *Biometrika* 46: 441-53; December 1959.

CURETON, EDWARD E. "The Average Spearman Rank Criterion Correlation When Ties Are Present." *Psychometrika* 23: 271-72; September 1958.

CURETON, EDWARD E. "A Note on Factor Analysis: Arbitrary Orthogonal Transformations." *Psychometrika* 24: 169-74; June 1959.

DALENIUS, TORE, and HODGES, JOSEPH L., JR. "Minimum Variance Stratification." *Journal of the American Statistical Association* 54: 88-101; March 1959.

DARLING, D. A. "The Kolmogorov-Smirnov, Cramér-Von Mises Tests." *Annals of Mathematical Statistics* 28: 823-38; December 1957.

DARWIN, J. H. "On Corrections to the Chi-Squared Distribution." *Journal of the Royal Statistical Society* (Series B, Methodological) 20: 387-92; No. 2, 1958.

DAVID, H. A., and ARENS, BEVERLY E. "Optimal Spacing in Regression Analysis." *Annals of Mathematical Statistics* 30: 1072-81; December 1959.

DAVID, HERBERT T. "A Three-Sample Kolmogorov-Smirnov Test." *Annals of Mathematical Statistics* 29: 842-51; September 1958.

DEGROOT, MORRIS H. "Unbiased Sequential Estimation for Binomial Populations." *Annals of Mathematical Statistics* 30: 80-101; March 1959.

DEGROOT, MORRIS H., and NADLER, JACK. "Some Aspects of the Use of the Sequential Probability Ratio Test." *Journal of the American Statistical Association* 53: 187-99; March 1958.

DEMPSTER, A. P. "A High Dimensional Two Sample Significance Test." *Annals of Mathematical Statistics* 29: 995-1010; December 1958.

DEMPSTER, A. P. "A Significance Test for the Separation of Two Highly Multivariate Small Samples." *Biometrics* 16: 41-50; March 1960.

DIAMOND, SOLOMON. *Information and Error.* New York: Basic Books, 1959. 307 p.

DICKMAN, KERN W. *Factorial Validity of a Rating Instrument.* Doctor's thesis. Champaign: University of Illinois, 1960. 153 p.

DIXON, WILFRID J. "Estimates of the Mean and Standard Deviation of a Normal Population." *Annals of Mathematical Statistics* 28: 806-809; September 1957.

DIXON, WILFRID J. "Simplified Estimation from Censored Normal Samples." *Annals of Mathematical Statistics* 31: 385-91; June 1960.

DOWNIE, N. M., and HEATH, R. W. *Basic Statistical Methods.* New York: Harper & Brothers, 1959. 289 p.

DUBOIS, PHILIP H. *Multivariate Correlational Analysis.* New York: Harper & Brothers, 1957. 202 p.

DUBOIS, PHILIP H. "An Analysis of Guttman's Simplex." *Psychometrika* 25: 173-82; June 1960.

DUNN, OLIVE JEAN. "Estimation of the Means of Dependent Variables." *Annals of Mathematical Statistics* 29: 1095-1111; December 1958.

DUNN, OLIVE JEAN. "Confidence Intervals for the Means of Dependent, Normally Distributed Variables." *Journal of the American Statistical Association* 54: 613-21; September 1959. (a)

DUNN, OLIVE JEAN. "Estimation of the Medians for Dependent Variables." *Annals of Mathematical Statistics* 30: 192-97; March 1959. (b)

DUNNETT, CHARLES W. "On Selecting the Largest of k Normal Population Means." *Journal of the Royal Statistical Society* (Series B, Methodological) 22: 1-40; No. 1, 1960.

EDWARDS, ALLEN L. *Experimental Design in Psychological Research.* Revised edition. New York: Rinehart & Co., 1960. 398 p.

EMMENS, C. W. "The Role of Statistics in Physiological Research." *Biometrics* 16: 161-75; June 1960.

EZEKIEL, MORDECAI, and FOX, KARL A. *Methods of Correlation and Regression Analysis.* Third edition. New York: John Wiley & Sons, 1959. 548 p.

FEDERIGHI, ENRICO T. "Extended Tables of the Percentage Points of Student's t-Distribution." *Journal of the American Statistical Association* 54: 683-88; September 1959.

FELLER, WILLIAM. *An Introduction to Probability Theory and Its Applications.* Second edition. New York: John Wiley & Sons, 1957. Vol. I, 461 p.

FERGUSON, GEORGE A. *Statistical Analysis in Psychology and Education.* New York: McGraw-Hill Book Co., 1959. 347 p.

FIELLER, E. C.; HARTLEY, H. O.; and PEARSON, E. S. "I. Tests for Rank Correlation Coefficients." *Biometrika* 44: 470-81; December 1957.

FINKBEINER, DANIEL T. *Introduction to Matrices and Linear Transformations.* San Francisco: W. H. Freeman & Co., 1960. 248 p.

FINNEY, D. J. "The Efficiencies of Alternative Estimators for an Asymptotic Regression Equation." *Biometrika* 45: 370-88; December 1958.

FISHER, SIR RONALD A. *Statistical Methods and Scientific Inference.* New York: Hafner Publishing Co., 1956. 175 p.

FISHER, SIR RONALD A. "Mathematical Probability in the Natural Sciences." *Technometrics* 1: 21-29; February 1959.

FISHER, WALTER D. "On Grouping for Maximum Homogeneity." *Journal of the American Statistical Association* 53: 789-98; December 1958.

FOOTE, RICHARD J. "A Modified Doolittle Approach for Multiple and Partial Correlation and Regression." *Journal of the American Statistical Association* 53: 133-43; March 1958.

FRASER, DONALD A. S. "Most Powerful Rank-Type Tests." *Annals of Mathematical Statistics* 28: 1040-43; December 1957.

FRUCHTER, BENJAMIN, and FLEISHMAN, EDWIN A. "A Comparison of Two Approaches to Analyzing Correlations among Experimentally Dependent Variables." (Abstract) *American Psychologist* 12: 438; July 1957.

FRUCHTER, BENJAMIN, and NOVAK, EDWIN. "A Comparative Study of Three Methods of Rotation." *Psychometrika* 23: 211-21; September 1958.

GAITO, JOHN. "Nonparametric Methods in Psychological Research." *Psychological Reports* 5: 115-25; March 1959.

GIBSON, WILFRED A. "Three Multivariate Models: Factor Analysis, Latent Structure Analysis, and Latent Profile Analysis." *Psychometrika* 24: 229-52; September 1959.

GIBSON, WILFRED A. "Remarks on Tucker's Inter-Battery Method of Factor Analysis." *Psychometrika* 25: 19-25; March 1960.

GNANADESIKAN, R. "Equality of More than Two Variances and of More than Two Dispersion Matrices Against Certain Alternatives." *Annals of Mathematical Statistics* 30: 177-84; March 1959.

GOLDFRIED, MARVIN R. "Theoretical Note: One-Tailed Tests and 'Unexpected' Results." *Psychological Review* 66: 79-80; January 1959.

GOOD, IRVING J. "Significance Tests in Parallel and in Series." *Journal of the American Statistical Association* 53: 799-813; December 1958.

GOODMAN, LEO A. "Simplified Runs Tests and Likelihood Ratio Tests for Markoff Chains." *Biometrika* 45: 181-97; June 1958.

GOODMAN, LEO A. "Partial Tests for Partial Taus." *Biometrika* 46: 425-32; December 1959.

GOODMAN, LEO A., and HARTLEY, HERMAN O. "The Precision of Unbiased Ratio-Type Estimators." *Journal of the American Statistical Association* 53: 491-508; June 1958.

GOODMAN, LEO A., and KRUSKAL, WILLIAM H. "Measures of Association for Cross Classifications: II. Further Discussion and References." *Journal of the American Statistical Association* 54: 123-63; March 1959.

GRANT, DAVID A. "Statistical Methods." *Annual Review of Psychology.* (Edited by Paul R. Farnsworth and Quinn McNemar.) Stanford, Calif.: Annual Reviews, 1959. Vol. 10, p. 131-46.

GRAYBILL, FRANKLIN A. "Determining Sample Size for a Specified Width Confidence Interval." *Annals of Mathematical Statistics* 29: 282-87; March 1958.

GRAYBILL, FRANKLIN A., and DEAL, R. B. "Combining Unbiased Estimators." *Biometrics* 15: 543-50; December 1959.

GREENBERG, BERNARD G., and SARHAN, AHMED E. "Matrix Inversion, Its Interest and Application in Analysis of Data." *Journal of the American Statistical Association* 54: 755-66; December 1959.

GRIDGEMAN, N. T. "The Lady Tasting Tea, and Allied Topics." *Journal of the American Statistical Association* 54: 776-83; December 1959.

GRIFFIN, HAROLD D. "Graphic Computation of Tau as a Coefficient of Disarray." *Journal of the American Statistical Association* 53: 441-47; June 1958.

GULLIKSEN, HAROLD, and MESSICK, SAMUEL, editors. *Psychological Scaling: Theory and Applications.* New York: John Wiley & Sons, 1960. 211 p.

GUPTA, SHANTI S., and SOBEL, MILTON. "On Selecting a Subset Which Contains All Populations Better than a Standard." *Annals of Mathematical Statistics* 29: 235-44; March 1958.

GUTTMAN, LOUIS. "Empirical Verification of the Radex Structure of Mental Abilities and Personality Traits." *Educational and Psychological Measurement* 17: 391-407; Autumn 1957.

GUTTMAN, LOUIS. "To What Extent Can Communalities Reduce Rank?" *Psychometrika* 23: 297-308; December 1958. (a)

GUTTMAN, LOUIS. "What Lies Ahead for Factor Analysis?" *Educational and Psychological Measurement* 18: 497-515; Autumn 1958. (b)

GUTTMAN, LOUIS. "Metricizing Rank-Ordered or Unordered Data for a Linear Factor Analysis." *Sankhyā* 21: 257-68; August 1959.

HACK, H. R. B. "An Empirical Investigation into the Distribution of the F-Ratio in Samples from Two Non-Normal Populations." *Biometrika* 45: 260-65; June 1958.

HAGGARD, ERNEST A. *Intraclass Correlation and the Analysis of Variance.* New York: Dryden Press, 1958. 171 p.

HALDANE, J. B. S. "I. The Analysis of Heterogeneity." *Sankhyā* 21: 209-16; August 1959.

HALPERIN, MAX. "Extension of the Wilcoxon-Mann-Whitney Test to Samples Censored at the Same Fixed Point." *Journal of the American Statistical Association* 55: 125-38; March 1960.

HARMAN, HARRY H. "Statistical Methods." *Annual Review of Psychology.* (Edited by Paul R. Farnsworth and Quinn McNemar.) Stanford, Calif.: Annual Reviews, 1958. Vol. 9, p. 213-42.

HARTER, H. LEON. "The Use of Sample Quasi-Ranges in Estimating Population Standard Deviation." *Annals of Mathematical Statistics* 30: 980-99; December 1959.

HARTLEY, H. O. "Maximum Likelihood Estimation from Incomplete Data." *Biometrics* 14: 174-94; June 1958.

HAYS, WILLIAM L. "A Note on Average Tau as a Measure of Concordance." *Journal of the American Statistical Association* 55: 331-41; June 1960.

HOFFMAN, PAUL J. "Generating Variables with Arbitrary Properties." *Psychometrika* 24: 265-67; September 1959.

HOGBEN, LANCELOT. *Statistical Theory: The Relationship of Probability, Credibility, and Error.* New York: W. W. Norton & Co., 1957. 510 p.

HOHN, FRANZ E. *Elementary Matrix Algebra.* New York: Macmillan Co., 1958. 305 p.

HOOPER, JOHN W. "The Sampling Variance of Correlation Coefficients Under Assumptions of Fixed and Mixed Variates." *Biometrika* 45: 471-77; December 1958.

HOTELLING, HAROLD. "The Relations of the Newer Multivariate Statistical Methods to Factor Analysis." *British Journal of Statistical Psychology* 10: 69-79; November 1957.

HOYT, CYRIL J.; KRISHNAIAH, P. R.; and TORRANCE, E. PAUL. "Analysis of Complex Contingency Data." *Journal of Experimental Education* 27: 187-94; March 1959.

IRWIN, J. O. "On the Estimation of the Mean of a Poisson Distribution from a Sample with the Zero Class Missing." *Biometrics* 15: 324-26; June 1959.

JAMES, ALAN T. "The Distribution of the Latent Roots of the Covariance Matrix." *Annals of Mathematical Statistics* 31: 151-58; March 1960.

JAMES, G. S. "The Behrens-Fisher Distribution and Weighted Means." *Journal of the Royal Statistical Society* (Series B, Methodological) 21: 73-90; No. 1, 1959.

JEFFREYS, HAROLD. *Scientific Inference.* Second edition. New York: Cambridge University Press, 1957. 236 p.

JOHNSON, N. L. "An Approximation to the Multinomial Distribution: Some Properties and Applications." *Biometrika* 47: 93-102; June 1960.

JOHNSON, PALMER O., and JACKSON, ROBERT W. B. *Modern Statistical Methods: Descriptive and Inductive.* Chicago: Rand McNally & Co., 1959. 514 p.

JONES, HOWARD L. "Inadmissible Samples and Confidence Limits." *Journal of the American Statistical Association* 53: 482-90; June 1958.

JONES, HOWARD L. "How Many of a Group of Random Numbers Will Be Usable in Selecting a Particular Sample?" *Journal of the American Statistical Association* 54: 102-22; March 1959.

KAISER, HENRY F. "The Varimax Criterion for Analytic Rotation in Factor Analysis." *Psychometrika* 23: 187-200; September 1958.

KAISER, HENRY F. "Computer Program for Varimax Rotation in Factor Analysis." *Educational and Psychological Measurement* 19: 413-20; Autumn 1959. (a)

KAISER, HENRY F. "A Note on the Tryon-Kaiser Solution for the Communalities." *Psychometrika* 24: 269-71; September 1959. (b)

KAISER, HENRY F. *Alpha Reliability of Factors.* Urbana: University of Illinois, Bureau of Educational Research, 1960. 19 p. (Mimeo.) (a)

KAISER, HENRY F. "The Application of Electronic Computers to Factor Analysis." *Educational and Psychological Measurement* 20: 141-51; Spring 1960. (b)

KAISER, HENRY F. "Directional Statistical Decisions." *Psychological Review* 67: 160-67; May 1960. (c)

KAISER, HENRY F. "Varimax Solution for Primary Mental Abilities." *Psychometrika* 25: 153-58; June 1960. (d)

KAISER, HENRY F., and DICKMAN, KERN W. "Analytic Determination of Common Factors." (Abstract) *American Psychologist* 14: 425; July 1959.

KARON, BERTRAM P., and ALEXANDER, IRVING E. "A Modification of Kendall's Tau for Measuring Association in Contingency Tables." *Psychometrika* 23: 379-83; December 1958.

KARST, OTTO J. "Linear Curve Fitting Using Least Deviations." *Journal of the American Statistical Association* 53: 118-32; March 1958.

KASTENBAUM, MARVIN A. "A Confidence Interval on the Abscissa of the Point of Intersection of Two Fitted Linear Regressions." *Biometrics* 15: 323-24; June 1959.

KASTENBAUM, MARVIN A., and LAMPHIEAR, DONALD E. "Calculation of Chi-Square to Test the No Three-Factor Interaction Hypothesis." *Biometrics* 15: 107-15; March 1959.

KEMENY, JOHN G.; SNELL, J. LAURIE; and THOMPSON, GERALD L. *Introduction to Finite Mathematics.* Englewood Cliffs, N.J.: Prentice-Hall, 1957. 372 p.

KENDALL, MAURICE G. *A Course in Multivariate Analysis.* Griffin's Statistical Monographs and Courses, No. 2. London: Charles Griffin & Co., 1957. New York: Hafner Publishing Co., 1957. 185 p.

KENDALL, MAURICE G., and BUCKLAND, WILLIAM R. *A Dictionary of Statistical Terms.* London: Oliver & Boyd, 1957. 493 p.

KENDALL, MAURICE G., and STUART, ALAN. *The Advanced Theory of Statistics. Vol. I. Distribution Theory.* New revised edition. London: Charles Griffin & Co., 1958. New York: Hafner Publishing Company, 1958. 433 p.

KESTEN, HARRY, and MORSE, NORMAN. "A Property of the Multinomial Distribution." *Annals of Mathematical Statistics* 30: 120-27; March 1959.

KHATRI, CHINUBBAI G. "On Testing the Equality of Parameters in k Rectangular Populations." *Journal of the American Statistical Association* 55: 144-47; March 1960.

KIEFER, J. "K-Sample Analogues of the Kolmogorov-Smirnov and Cramér-Von Mises Tests." *Annals of Mathematical Statistics* 30: 420-47; June 1959.

KIEFER, J., and WOLFOWITZ, J. "Optimum Designs in Regression Problems." *Annals of Mathematical Statistics* 30: 271-94; June 1959.

KIMMEL, HERBERT D. "Three Criteria for the Use of One-Tailed Tests." *Psychological Bulletin* 54: 351-53; July 1957.

KISH, LESLIE, and HESS, IRENE. "On Variances of Ratios and Their Differences in Multi-Stage Samples." *Journal of the American Statistical Association* 54: 416-46; June 1959.

KLOTZ, JEROME. "Null Distribution of the Hodges Bivariate Sign Test." *Annals of Mathematical Statistics* 30: 1029-33; December 1959.

KOGAN, LEONARD S. "Statistics." *Annual Review of Psychology.* (Edited by Paul R. Farnsworth and Quinn McNemar.) Stanford, Calif.: Annual Reviews, 1960. Vol. II, p. 199-224.

KRUSKAL, WILLIAM H. "Historical Notes on the Wilcoxon Unpaired Two-Sample Test." *Journal of the American Statistical Association* 52: 356-60; September 1957.

KRUSKAL, WILLIAM H. "Ordinal Measures of Association." *Journal of the American Statistical Association* 53: 814-61; December 1958.

KUANG, H. P. "On a Test of Whether Two Sets of Observations Belong to a Certain Class of Distributions When the Random Variables Are Not Independent." *Journal of Experimental Education* 28: 267-68; March 1960.

KULLBACK, SOLOMON. *Information Theory and Statistics.* New York: John Wiley & Sons, 1959. 395 p.

KUPPERMAN, MORTON. "A Rapid Significance Test for Contingency Tables." *Biometrics* 15: 625-28; December 1959.

LANCASTER, H. O. "The Structure of Bivariate Distributions." *Annals of Mathematical Statistics* 29: 719-36; September 1958.

LAUBSCHER, N. F. "Note on Fisher's Transformation of the Correlation Coefficient." *Journal of the Royal Statistical Society* (Series B, Methodological) 21: 409-10; No. 2, 1959.

LAWLEY, D. N. "Estimation in Factor Analysis under Various Initial Assumptions." *British Journal of Statistical Psychology* 11: 1-12; May 1958.

LAWLEY, D. N. "Tests of Significance in Canonical Analysis." *Biometrika* 46: 59-66; June 1959.

LEHMANN, ERICH L. "Significance Level and Power." *Annals of Mathematical Statistics* 29: 1167-76; December 1958.

LEHMANN, ERICH L. "Optimum Invariant Tests." *Annals of Mathematical Statistics* 30: 881-84; December 1959. (a)

LEHMANN, ERICH L. *Testing Statistical Hypotheses.* New York: John Wiley & Sons, 1959. 369 p. (b)

LEWIS, DON. *Quantitative Methods in Psychology.* New York: McGraw-Hill Book Co., 1960. 558 p.

LINHART, H. "A Criterion for Selecting Variables in a Regression Analysis." *Psychometrika* 25: 45-58; March 1960. (a)

LINHART, H. "Measure of Predictive Precision in Regression Analysis." *Annals of Mathematical Statistics* 31: 399-404; June 1960. (b)

LORD, FREDERIC M. "Large-Sample Covariance Analysis When the Control Variable is Fallible." *Journal of the American Statistical Association* 55: 307-30; June 1960.

LUCE, R. DUNCAN. *Individual Choice Behavior: A Theoretical Analysis.* New York: John Wiley & Sons, 1959. 153 p.

LUCE, R. DUNCAN, and RAIFFA, HOWARD. *Games and Decisions: Introduction and Critical Survey.* New York: John Wiley & Sons, 1957. 509 p.

MCGREGOR, J. R. "An Approximate Test for Serial Correlation in Polynomial Regression." *Biometrika* 47: 111-19; June 1960.

MACHOL, ROBERT E., editor. *Information and Decision Processes.* New York: McGraw-Hill Book Co., 1960. 185 p.

MCHUGH, RICHARD B. "Note on 'Efficient Estimation and Local Identification in Latent Class Analysis.'" *Psychometrika* 23: 273-74; September 1958.

MACK, SIDNEY F. *Elementary Statistics.* New York: Henry Holt & Co., 1960. 198 p.

MACKAY, JOHN H. "Asymptotically Efficient Tests Based on the Sums of Observations." *Annals of Mathematical Statistics* 30: 806-13; September 1959.

MACKINNON, WILLIAM J. "Compact Table of Twelve Probability Levels of the Symmetric Binomial Cumulative Distribution for Sample Sizes to 1000." *Journal of the American Statistical Association* 54: 164-72; March 1959.

MADANSKY, ALBERT. "The Fitting of Straight Lines When Both Variables Are Subject to Error." *Journal of the American Statistical Association* 54: 173-205; March 1959.

MADANSKY, ALBERT. "Determinantal Methods in Latent Class Analysis." *Psychometrika* 25: 183-98; June 1960.

MANDEL, JOHN. "Fitting a Straight Line to Certain Types of Cumulative Data." *Journal of the American Statistical Association* 52: 552-66; December 1957.

MANDEL, JOHN. "A Note on Confidence Intervals in Regression Problems." *Annals of Mathematical Statistics* 29: 903-907; September 1958.

MASUYAMA, MOTOSABURO. "The Use of Sample Range in Estimating the Standard Deviation or the Variance of Any Population." *Sankhyā* 18: 159-62; May 1957.

MAURICE, RITA J. "A Minimax Procedure for Choosing Between Two Populations Using Sequential Sampling." *Journal of the Royal Statistical Society* (Series B, Methodological) 19: 255-61; No. 2, 1957.

MAURICE, RITA J. "Ranking Means of Two Normal Populations With Unknown Variances." *Biometrika* 45: 250-52; June 1958.

MAXWELL, A. E. *Experimental Design in Psychology and the Medical Sciences.* New York: John Wiley & Sons, 1958. 147 p.

MAXWELL, A. E. "Statistical Methods in Factor Analysis." *Psychological Bulletin* 56: 228-35; May 1959.

MAYO, SAMUEL T. "Toward Strengthening the Contingency Table as a Statistical Method." *Psychological Bulletin* 56: 461-70; November 1959.

MERRINGTON, MAXINE, and PEARSON, E. S. "An Approximation to the Distribution of Non-Central t." *Biometrika* 45: 484-91; December 1958.

MICHAEL, WILLIAM B.; KAISER, HENRY F.; and CLARK, CHERRY ANN. "Research Tools: Statistical Methods." *Review of Educational Research* 27: 498-527; December 1957.

MICKEY, MAX R. "Some Finite Population Unbiased Ratio and Regression Estimators." *Journal of the American Statistical Association* 54: 594-612; September 1959.

MIDDLETON, DAVID. *An Introduction to Statistical Communication Theory.* New York: McGraw-Hill Book Co., 1960. 1140 p.

MINCER, JACOB. "Applications of a New Graphic Method in Statistical Measurement." *Journal of the American Statistical Association* 52: 472-78; December 1957.

MOONAN, WILLIAM J. "A Table of Normal Distribution Frequencies for Selected Numbers of Class Intervals and Sample Sizes." *Journal of Experimental Education* 27: 231-35; March 1959.

MOORE, PETER G. "The Two-Sample t-test Based on Range." *Biometrika* 44: 482-89; December 1957.

MURDOCH, DAVID C. *Linear Algebra for Undergraduates.* New York: John Wiley & Sons, 1957. 239 p.

MURTHY, M. N. "Ordered and Unordered Estimators in Sampling Without Replacement." *Sankhyā* 18: 379-90; September 1957.

NANJAMMA, N. S.; MURTHY, M. N.; and SETHI, V. K. "Some Sampling Systems Providing Unbiased Ratio Estimators." *Sankhyā* 21: 299-314; August 1959.

NASS, C. A. G. "The χ^2 Test for Small Expectations in Contingency Tables, With Special Reference to Accidents and Absenteeism." *Biometrika* 46: 365-85; December 1959.

NICHOLSON, GEORGE E., JR. "Estimation of Parameters from Incomplete Multivariate Samples." *Journal of the American Statistical Association* 52: 523-26; December 1957.

OLKIN, INGRAM, and PRATT, JOHN W. "Unbiased Estimation of Certain Correlation Coefficients." *Annals of Mathematical Statistics* 29: 201-11; March 1958.

PACHARES, J. "Table of the Upper 10% Points of the Studentized Range." *Biometrika* 46: 461-66; December 1959.

PARKER, WILLIAM V., and EAVES, JAMES C. *Matrices.* New York: Ronald Press Co., 1960. 195 p.

PILLAI, K. C. SREEDHARAN, and SAMSON, PABLO, JR. "On Hotelling's Generalization of T^2." *Biometrika* 46: 160-68; June 1959.

PILLAI, K. C. SREEDHARAN, and TIENZO, BENJAMIN P. "On the Distribution of the Extreme Studentized Deviate from the Sample Mean." *Biometrika* 46: 467-74; December 1959.

PRATT, JOHN W. "Remarks on Zeros and Ties in the Wilcoxon Signed Rank Procedures." *Journal of the American Statistical Association* 54: 655-67; September 1959.

QUANDT, RICHARD E. "The Estimation of the Parameters of a Linear Regression System Obeying Two Separate Regimes." *Journal of the American Statistical Association* 53: 873-80; December 1958.

QUANDT, RICHARD E. "Tests of the Hypothesis that a Linear Regression System Obeys Two Separate Regimes." *Journal of the American Statistical Association* 55: 324-30; June 1960.

QUENOUILLE, MAURICE H. "Tables of Random Observations from Standard Distributions." *Biometrika* 46: 178-202; June 1959.

RAJ, DES, and KHAMIS, SALEM H. "Some Remarks on Sampling With Replacement." *Annals of Mathematical Statistics* 29: 550-57; June 1958.

RAMACHANDRAN, KODUVAYUR V. "On the Studentized Smallest Chi-Square." *Journal of the American Statistical Association* 53: 868-72; December 1958. (a)

RAMACHANDRAN, KODUVAYUR V. "A Test of Variances." *Journal of the American Statistical Association* 53: 741-47; September 1958. (b)

RAO, C. RADHAKRISHNA. "Maximum Likelihood Estimation for the Multinomial Distribution." *Sankhyā* 18: 139-48; May 1957.

RAO, C. RADHAKRISHNA. "Maximum Likelihood Estimation for the Multinomial Distribution with Infinite Number of Cells." *Sankhyā* 20: 211-18; December 1958.

RAO, C. RADHAKRISHNA. "Some Problems Involving Linear Hypotheses in Multivariate Analysis." *Biometrika* 46: 49-58; June 1959.

RAO, U. V. R.; SAVAGE, I. RICHARD; and SOBEL, MILTON. "Contributions to the Theory of Rank Order Statistics: The Two-Sample Censored Case." *Annals of Mathematical Statistics* 31: 415-26; June 1960.

RAY, W. D. "Sequential Confidence Intervals for the Mean of a Normal Population with Unknown Variance." *Journal of the Royal Statistical Society* (Series B, Methodological) 19: 133-43; No. 1, 1957.

RAY, WILLIAM S. *An Introduction to Experimental Design.* New York: Macmillan Co., 1960. 254 p.

ROY, J., and CHAKRAVARTI, I. M. "Estimating the Mean of a Finite Population." *Annals of Mathematical Statistics* 31: 392-98; June 1960.

ROY, SAMARENDRA N. *Some Aspects of Multivariate Analysis.* New York: John Wiley & Sons, 1957. 214 p.

ROY, SAMARENDRA N., and GNANADESIKAN, R. "Further Contributions to Multivariate Confidence Bounds." *Biometrika* 44: 399-410; December 1957.

ROY, SAMARENDRA N., and POTTHOFF, R. F. "Confidence Bounds on Vector Analogues of the 'Ratio of Means' and the 'Ratio of Variances' for the Two Correlated Normal Variates and Some Associated Tests." *Annals of Mathematical Statistics* 29: 829-41; September 1958.

SANKARAN, MUNUSWAMY. "On Nair's Transformation of the Correlation Coefficient." *Biometrika* 45: 567-71; December 1958.

SARHAN, AHMED E., and GREENBERG, B. G. "Estimation of Location and Scale Parameters for the Rectangular Population from Censored Samples." *Journal of the Royal Statistical Society* (Series B, Methodological) 21: 356-63; No. 2, 1959.

SARHAN, AHMED E., and GREENBERG, B. G. "Estimation of Location and Scale Parameters by Order Statistics from Singly and Doubly Censored Samples: II. Tables for the Normal Distribution for Samples of Size $11 \leqq n \leqq 15$." *Annals of Mathematical Statistics* 29: 79-105; March 1958.

SATHE, Y. S., and KAMAT, A. R. "Approximations to the Distributions of Some Measures of Dispersion Based on Successive Differences." *Biometrika* 44: 349-59; December 1957.

SAVAGE, I. RICHARD. "Contributions to the Theory of Rank Order Statistics—The 'Trend' Case." *Annals of Mathematical Statistics* 28: 968-77; December 1957.

SAVAGE, I. RICHARD. "Contributions to the Theory of Rank Order Statistics: Computation Rules for Probabilities of Rank Orders." *Annals of Mathematical Statistics* 31: 519-20; June 1960.

SAW, J. G. "Moments of Sample Moments of Censored Samples from a Normal Population." *Biometrika* 45: 211-21; June 1958.

SAW, J. G. "Estimation of the Normal Population Parameters Given a Singly Censored Sample." *Biometrika* 46: 150-59; June 1959.

SAWREY, WILLIAM L. "A Distinction Between Exact and Approximate Nonparametric Methods." *Psychometrika* 23: 171-77; June 1958.

SCHEFFÉ, HENRY. "Fitting Straight Lines when One Variable is Controlled." *Journal of the American Statistical Association* 53: 106-17; March 1958.

SCHUMANN, D. E. W., and BRADLEY, R. A. "The Comparison of the Sensitivities of Similar Experiments: Theory." *Annals of Mathematical Statistics* 28: 902-20; December 1957.

SCHUTZ, WILLIAM C. "The Little Jiffy Correlator: A Simple Technique for a Complex Analysis of Large Numbers of Measures on the Same Individuals." *Educational and Psychological Measurement* 20: 111-18; Spring 1960.

SEAL, KIRON C. "A Single Sampling Plan for Correlated Variables with a Single-Sided Specification Limit." *Journal of the American Statistical Association* 54: 248-59; March 1959.

SENDERS, VIRGINIA L. *Measurement and Statistics: A Basic Text Emphasizing Behavioral Science Applications.* New York: Oxford University Press, 1958. 594 p.

SHAKLEE, ALFRED B. "A Note on Significance Tests." *Psychological Reports* 4: 598; December 1957.

SHEPS, MINDEL C. "An Examination of Some Methods of Comparing Several Rates or Proportions." *Biometrics* 15: 87-97; March 1959.

SIDDIQUI, M. M. "Distribution of a Serial Correlation Coefficient Near the Ends of the Range." *Annals of Mathematical Statistics* 29: 852-61; September 1958.

SIEGEL, SIDNEY, and FOURAKER, LAWRENCE E. *Bargaining and Group Decision Making.* New York: McGraw-Hill Book Co., 1960. 132 p.

SILVERSTEIN, A. B. "Nonparametric Tests for the Comparison of Changes." *Psychological Reports* 4: 582; December 1958.

SILVERSTONE, H. "Estimating the Logistic Curve." *Journal of the American Statistical Association* 52: 567-77; December 1957.

SNEDECOR, GEORGE W. "Chi-Squares of Bartlett, Mood, and Lancaster in a 2^2 Contingency Table." *Biometrics* 14: 560-62; December 1958.

SNEDECOR, GEORGE W. *Statistical Methods.* Revised edition. Ames: Iowa State College Press, 1960. 534 p.

SOKAL, ROBERT R. "Thurstone's Analytical Method for Simple Structure and a Mass Modification Thereof." *Psychometrika* 23: 237-57; September 1958.

SOMERS, ROBERT H. "The Rank Analogue of Product-Moment Partial Correlation and Regression, with Application to Manifold, Ordered Contingency Tables." *Biometrika* 46: 241-46; June 1959.

SOMERVILLE, PAUL N. "Optimum Sampling in Binomial Populations." *Journal of the American Statistical Association* 52: 494-502; December 1957.

SOMERVILLE, PAUL N. "Tables for Obtaining Non-Parametric Tolerance Limits." *Annals of Mathematical Statistics* 29: 599-601; June 1958.

SPROTT, D. A. "The Method of Maximum Likelihood Applied to the Poisson Binomial Distribution." *Biometrics* 14: 97-106; March 1958.

SRIVASTAVA, A. B. L. "Effect of Non-Normality on the Power Function of t-Test." *Biometrika* 45: 421-29; December 1958.

SRIVASTAVA, A. B. L. "The Distribution of Regression Coefficients in Samples from Bivariate Non-Normal Populations: I. Theoretical Investigation." *Biometrika* 47: 61-68; June 1960.

STECK, GEORGE P. "A Table for Computing Trivariate Normal Probabilities." *Annals of Mathematical Statistics* 29: 780-800; September 1958.

STEEL, ROBERT G. D. "A Multiple Comparison Rank Sum Test: Treatments Versus Control." *Biometrics* 15: 560-572. December 1959. (a)

STEEL, ROBERT G. D. "A Multiple Comparison Sign Test: Treatments Versus Control." *Journal of the American Statistical Association* 54: 767-75; December 1959. (b)

STEEL, ROBERT G. D. "A Rank Sum Test for Comparing All Pairs of Treatments." *Technometrics* 2: 197-207; May 1960.

STEIN, CHARLES. "A Two-Sample Test for a Linear Hypothesis Whose Power Is Independent of the Variance." *Annals of Mathematical Statistics* 16: 243-58; March 1945.

STEIN, CHARLES. "An Example of Wide Discrepancy Between Fiducial and Confidence Intervals." *Annals of Mathematical Statistics* 30: 877-80; December 1959.

STEINHAUS, H. "The Problem of Estimation." *Annals of Mathematical Statistics* 28: 633-48; September 1957.

STERLING, THEODORE D. "Publication Decisions and Their Possible Effects on Inferences Drawn from Tests of Significance—or Vice Versa." *Journals of the American Statistical Association* 54: 30-34; March 1959.

STEVENS, W. L. "Shorter Intervals for the Parameter of the Binomial and Poisson Distributions." *Biometrika* 44: 436-40; December 1957.

STEVENS, W. L. "Sampling without Replacement with Probability Proportional to Size." *Journal of the Royal Statistical Society* (Series B, Methodological) 20: 393-97; No. 2, 1958.

SUITS, DANIEL B. "Use of Dummy Variables in Regression Equations." *Journal of the American Statistical Association* 52: 548-51; December 1957.

SUKHATME, BALKRISHNA V. "Testing the Hypothesis that Two Populations Differ Only in Location." *Annals of Mathematical Statistics* 29: 60-78; March 1958. (a)

SUKHATME, BALKRISHNA V. "A Two Sample Distribution Free Test for Comparing Variances." *Biometrika* 45: 544-48; December 1958. (b)

TANNER, J. C. "A Problem in the Combination of Accident Frequencies." *Biometrika* 45: 331-42; December 1958.

TATE, MERLE W., and CLELLAND, RICHARD C. *Nonparametric and Shortcut Statistics.* Danville, Ill.: Interstate Printers and Publishers, 1957. 171 p.

TATE, ROBERT F. "Unbiased Estimation: Functions of Location and Scale Parameters." *Annals of Mathematical Statistics* 30: 341-66; June 1959.

TATE, ROBERT F., and GOEN, R. L. "Minimum Variance Unbiased Estimation for the Truncated Poisson Distribution." *Annals of Mathematical Statistics* 29: 755-65; September 1958.

TATE, ROBERT F., and KLETT, GERALD W. "Optimal Confidence Intervals for the Variance of a Normal Distribution." *Journal of the American Statistical Association* 54: 674-82; September 1959.

TAYLOR, J. G. "IV. Scientific Method in Psychology." *British Journal of Statistical Psychology* 11: 133-36; November 1958.

THRALL, ROBERT M., and TORNHEIM, LEONARD. *Vector Spaces and Matrices.* New York: John Wiley & Sons, 1957. 318 p.

THURSTONE, LOUIS L. *The Measurement of Values.* Chicago: University of Chicago Press, 1959. 322 p.

TIKKIWAL, B. D. "On the Theory of Classical Regression and Double Sampling Estimation." *Journal of the Royal Statistical Society* (Series B, Methodological) 22: 131-38; No. 1, 1960.

TORGERSON, WARREN S. *Theory and Methods of Scaling.* New York: John Wiley & Sons, 1958. 460 p.

TRYON, ROBERT C. "Communality of a Variable: Formulation by Cluster Analysis." *Psychometrika* 22: 241-60; September 1957. (a)

TRYON, ROBERT C. "Cumulative Communality Cluster Analysis: An Alternative to Factor Analysis." (Abstract) *American Psychologist* 12: 438; July 1957. (b)

TRYON, ROBERT C. "Cumulative Communality Cluster Analysis." *Educational and Psychological Measurement* 18: 3-35; Spring 1958. (a)

TRYON, ROBERT C. "General Dimensions of Individual Differences: Cluster Analysis vs. Multiple Factor Analysis." *Educational and Psychological Measurement* 18: 477-95; Autumn 1958. (b)

TRYON, ROBERT C. "Domain Sampling Formulation of Cluster and Factor Analysis." *Psychometrika* 24: 113-35; June 1959.

TUCKER, LEDYARD R. "An Inter-Battery Method of Factor Analysis." *Psychometrika* 23: 111-36; June 1958.
TUKEY, JOHN W. "A Quick, Compact, Two-Sample Test to Duckworth's Specifications." *Technometrics* 1: 31-48; February 1959.
TUKEY, JOHN W. "Where Do We Go From Here?" *Journal of the American Statistical Association* 55: 80-93; March 1960.
TURNER, MALCOLM E., and STEVENS, CHARLES D. "The Regression Analysis of Causal Paths." *Biometrics* 15: 236-58; June 1959.
TYLER, FRED, and MICHAEL, WILLIAM B. "An Empirical Study of the Comparability of Factor Structure When Unities and Communality Estimates Are Used." *Educational and Psychological Measurement* 18: 347-54; Summer 1958.
VAGHOLKAR, M. K., and WETHERILL, G. B. "The Most Economical Binomial Sequential Probability Ratio Test." *Biometrika* 47: 103-109; June 1960.
WAGNER, HARVEY M. "Linear Programming Techniques for Regression Analysis." *Journal of the American Statistical Association* 54: 206-12; March 1959.
WALKER, HELEN M., and LEV, JOSEPH. *Elementary Statistical Methods.* Revised edition. New York: Henry Holt & Co., 1958. 302 p.
WALLACE, DAVID L. "Bounds on Normal Approximations to Student's and the Chi-Square Distributions." *Annals of Mathematical Statistics* 30: 1121-30; December 1959. (a)
WALLACE, DAVID L. "Conditional Confidence Level Properties." *Annals of Mathematical Statistics* 30: 864-76; December 1959. (b)
WALLACE, DAVID L. "Simplified Beta-Approximations to the Kruskal-Wallace H Test." *Journal of the American Statistical Association* 54: 225-30; March 1959. (c)
WALSH, JOHN E. "Comments on 'The Simplest Signed-Rank Test.'" *Journal of the American Statistical Association* 54: 213-24; March 1959. (a)
WALSH, JOHN E. "Definition and Use of Generalized Percentage Points." *Sankhyā* 21: 281-88; August 1959. (b)
WALSH, JOHN E. "Exact Nonparametric Tests for Randomized Blocks." *Annals of Mathematical Statistics* 30: 1034-40; December 1959. (c)
WATSON, G. S. "The χ^2 Goodness-of-Fit Test for Normal Distributions." *Biometrika* 44: 336-48; December 1957.
WATSON, G. S. "On Chi-Square Goodness-of-Fit Tests for Continuous Distribution." *Journal of the Royal Statistical Society* (Series B, Methodological) 20: 44-72; No. 1, 1958.
WATSON, G. S. "Some Recent Results in Chi-Square Goodness-of-Fit Tests." *Biometrics* 15: 440-68; September 1959.
WATTERSON, G. A. "Linear Estimation in Censored Samples from Multivariate Normal Populations." *Annals of Mathematical Statistics* 30: 814-24; September 1959.
WAUGH, FREDERICK V., and FOX, KARL A. "Graphic Computation of $R_{1.23}$." *Journal of the American Statistical Association* 52: 479-81; December 1957.
WEINSTEIN, ABBOTT S. "Alternative Definitions of the Serial Correlation Coefficient in Short Autoregressive Sequences." *Journal of the American Statistical Association* 53: 881-92; December 1958.
WELCH, BERNARD L. "'Student' and Small Sample Theory." *Journal of the American Statistical Association* 53: 777-88; December 1958.
WESLER, OSCAR. "A Classification Problem Involving Multinomials." *Annals of Mathematical Statistics* 30: 128-33; March 1959.
WHERRY, ROBERT J. "Hierarchical Factor Solutions without Rotation." *Psychometrika* 24: 45-51; March 1959.
WHITE, JOHN S. "A t-Test for the Serial Correlation Coefficient." *Annals of Mathematical Statistics* 28: 1046-48; December 1957.
WHITTLE, P. "On the Smoothing of Probability Density Functions." *Journal of the Royal Statistical Society* (Series B, Methodological) 20: 334-43; No. 2, 1958.
WILLIAMS, EVAN J. "Simultaneous Regression Equations in Experimentation." *Biometrika* 45: 96-110; June 1958.
WILLIAMS, EVAN J. "Significance of Difference Between Two Non-Independent Correlation Coefficients." *Biometrics* 15: 135-36; March 1959.
WILLIS, RICHARD H. "Lower Bound Formulas for the Mean Intercorrelation Coefficient." *Journal of the American Statistical Association* 54: 275-80; March 1959.
WITTING, H. "A Generalized Pitman Efficiency for Non-parametric Tests." *Annals of Mathematical Statistics* 31: 405-414; June 1960.

WOLINS, LEROY. "An Improved Procedure for the Wherry-Winer Method for Factoring Large Numbers of Items." *Psychometrika* 24: 261-64; September 1959.
WORMLEIGHTON, R. "Some Tests of Permutation Symmetry." *Annals of Mathematical Statistics* 30: 1005-17; December 1959.
WORMLEIGHTON, R. "A Useful Generalization of the Stein Two-Sample Procedure." *Annals of Mathematical Statistics* 31: 217-21; March 1960.
WRIGHT, SEWALL. "Path Coefficients and Path Regressions: Alternative or Complementary Concepts?" *Biometrics* 16: 189-202; June 1960.
WRIGLEY, CHARLES. "The Case Against Communalities." (Abstract) *American Psychologist* 12: 452; July 1957. (a)
WRIGLEY, CHARLES. "The Distinction Between Common and Specific Variance in Factor Theory." *British Journal of Statistical Psychology* 10: 81-98; November 1957. (b)
WRIGLEY, CHARLES. "Objectivity in Factor Analysis." *Educational and Psychological Measurement* 18: 463-76; Autumn 1958.
WRIGLEY, CHARLES. "The Effect upon the Communalities of Changing the Estimate of the Number of Factors." *British Journal of Statistical Psychology* 12: 35-54; May 1959.
WRIGLEY, CHARLES; SAUNDERS, DAVID R.; and NEUHAUS, JACK O. "Application of the Quartimax Method of Rotation to Thurstone's Primary Mental Abilities Study." *Psychometrika* 23: 151-70; June 1958.
ZINGER, A., and ST-PIERRE, J. "On the Choice of the Best Amongst Three Normal Populations with Known Variances." *Biometrika* 45: 436-46; December 1958.

Additional References

AHMAVAARA, YRJÖ. *On the Unified Factor Theory of Mind.* Annales Akademiae Scientiarum Fennicae, Series B. Helsinki, Finland: Suomalaisen Tiedeakatemia, 1957. Vol. 106, 176 p.
AHMAVAARA, YRJÖ, and MARKKANEN, TOUKO. *The Unified Factor Model. Its Position in Psychometric Theory and Application to Sociological Alcohol Study.* Stockholm: Almqvist & Wiksells, 1958. Vol. 6, 187 p.
ALDER, HENRY L., and ROESSLER, EDWARD B. *Introduction to Probability and Statistics.* San Francisco: W. H. Freeman & Co., 1960. 252 p.
BAGGALEY, ANDREW R. "Matrix Formulation of Deuel's Rotational Method." *Psychometrika* 25: 207-209; June 1960.
BAILEY, NORMAN T. J. *Statistical Methods in Biology.* New York: John Wiley & Sons, 1959. 200 p.
BARTLETT, MAURICE S. *An Introduction to Stochastic Processes with Special Reference to Methods and Applications.* New York: Cambridge University Press, 1955. 312 p.
BERNYER, G. "Psychological Factors: Their Number, Nature and Identification." *British Journal of Statistical Psychology* 10: 17-27; May 1957.
BERNYER, G. "Second Order Factors and the Organization of Cognitive Functions." *British Journal of Statistical Psychology* 11: 19-29; May 1958.
BHARUCHA-REID, A. T. *Elements of the Theory of Markov Processes and their Applications.* New York: McGraw-Hill Book Co., 1960. 468 p.
BORGATTA, EDGAR F. "On Analyzing Correlation Matrices: Some New Emphases." *Public Opinion Quarterly* 22: 516-28; Winter 1958-59.
BURINGTON, RICHARD S., and MAY, DONALD C. *Handbook of Probability and Statistics with Tables.* New York: McGraw-Hill Book Co., 1959. 332 p.
BUSH, ROBERT R., and ESTES, WILLIAM K., editors. *Studies in Mathematical Learning Theory.* Stanford, Calif.: Stanford University Press, 1959. 432 p.
COX, DANIEL R. "Note on Grouping." *Journal of the American Statistical Association* 52: 543-47; December 1957.
CROW, EDWIN L. "The Mean Deviation of the Poisson Distribution." *Biometrika* 45: 556-59; December 1958.
DAVIDSON, DONALD; SUPPES, PATRICK; and SIEGEL, SIDNEY. *Decision Making: An Experimental Approach.* Stanford, Calif.: Stanford University Press, 1957. 121 p.
DEMAREE, ROBERT G. "A Method of Wide Applicability for Testing Hypotheses About the Structure of Qualitative Variables." (Abstract) *American Psychologist* 12: 452; July 1957.

DINGMAN, HARVEY F. "The Relation Between Coefficients of Correlation and Difficulty Factors." *British Journal of Statistical Psychology* 11: 13-17; May 1958.

DUBOIS, PHILIP H., and MANNING, WINTON H. "An Analytically Meaningful Approach to Matrix Computations." (Abstract) *American Psychologist* 14: 415; July 1959.

DWIGHT, LESLIE A. "The Mean or Average Deviation is a Minimum When Taken from the Median: A Geometric Proof." *Journal of Experimental Education* 26: 93-94; September 1957.

EDWARDS, ALLEN L. *Statistical Analysis.* Revised edition. New York: Rinehart & Co., 1958. 234 p.

EISENBERG, EDMUND, and GALE, DAVID. "Consensus of Subjective Probabilities: The Pari-Mutuel Method." *Annals of Mathematical Statistics* 30: 165-68; March 1959.

EPSTEIN, BENJAMIN. "Elements of the Theory of Extreme Values." *Technometrics* 2: 27-41; February 1960.

EPSTEIN, L. IVAN. *Nomography.* New York: Interscience Publishers, 1958. 144 p.

FINNEY, D. J. "On Combining Partial Correlation Coefficients." *Biometrics* 16: 118; March 1960.

FISHER, SIR RONALD A., and CORNISH, E. A. "The Percentile Points of Distributions Having Known Cumulants." *Technometrics* 2: 209-25; May 1960.

FRASER, DONALD A. S. *Statistics: An Introduction.* New York: John Wiley & Sons, 1958. 398 p.

FRENCH, JOHN W. "Kit of Factor Reference Tests." (Abstract) *American Psychologist* 14: 416; July 1959.

GARRETT, HENRY E. *Statistics in Psychology and Education.* Fifth edition. New York: Longmans, Green & Co., 1958. 478 p.

GARSIDE, R. F. "The Measurement of Function Fluctuation." *Psychometrika* 23: 75-83; March 1958.

GJEDDEBAEK, N. F. "Contribution to the Study of Grouped Observations: IV. Some Comments on Simple Estimates." *Biometrics* 15: 433-39; September 1959.

GOLDBERG, SAMUEL. *An Introduction to Difference Equations: With Illustrative Examples from Economics, Psychology, and Sociology.* New York: John Wiley & Sons, 1958. 260 p.

GOLDFARB, NATHAN. *An Introduction to Longitudinal Statistical Analysis.* Glencoe, Ill.: Free Press, 1960. 220 p.

GRENANDER, ULF, editor. *Probability and Statistics.* New York: John Wiley & Sons, 1959. 434 p.

GUMBEL, EMIL J. *Statistics of Extremes.* New York: Columbia University Press, 1958. 375 p.

GUPTA, SHANTI. "Order Statistics from the Gamma Distribution." *Technometrics* 2: 243-62; May 1960.

GUTTMAN, LOUIS, and GUTTMAN, RUTH. "An Illustration of the Use of Stochastic Approximation." *Biometrics* 15: 551-59; December 1959.

HALMOS, PAUL R. *Naive Set Theory.* Princeton, N.J.: D. Van Nostrand Co., 1960. 104 p.

HAMILTON, MAX. "An Experimental Approach to the Identification of Factors." *British Journal of Statistical Psychology* 11: 161-69; November 1958.

HENDRICKS, WALTER A. *The Mathematical Theory of Sampling.* New Brunswick, N.J.: Scarecrow Press, 1956. 364 p.

HOEL, PAUL G. *Elementary Statistics.* New York: John Wiley & Sons, 1960. 261 p.

HOGG, ROBERT V. "Certain Uncorrelated Statistics." *Journal of the American Statistical Association* 55: 265-67; June 1960.

HOGG, ROBERT V., and CRAIG, ALLEN T. *Introduction to Mathematical Statistics.* New York: Macmillan Co., 1959. 245 p.

HOYT, CYRIL J., and KRISHNAIAH, P. R. "Test of Significance of Differences of Changes." *Journal of Experimental Education* 26: 247-51; March 1958.

JOHNSON, N. L. "The Mean Deviation, with Special Reference to Samples from a Pearson Type III Population." *Biometrika* 45: 478-83; December 1958.

JOHNSON, N. L. "On an Extension of the Connexion Between Poisson and χ^2 Distributions." *Biometrika* 46: 352-63; December 1959.

JOHNSON, PALMER O., and RAO, MUNAMARTY S. *Modern Sampling Methods.* Minneapolis: University of Minnesota Press, 1959. 87 p.

KATZ, LEO, and POWELL, JAMES H. "Probability Distributions of Random Variables Associated with a Structure of the Sample Space of Sociometric Investigations." *Annals of Mathematical Statistics* 28: 442-48; June 1957.

KLINE, WILLIAM E. "A Synthesis of Two Factor Analyses of Intermediate Algebra." *Psychometrika* 24: 343-59; December 1959.

LEVENS, ALEXANDER S. *Nomography*. Second edition. New York: John Wiley & Sons, 1959. 296 p.

MCCARTHY, PHILIP J. *Introduction to Statistical Reasoning*. New York: McGraw-Hill Book Co., 1957. 402 p.

MENDENHALL, W., and LEHMANN, ERICH H., JR. "An Approximation to the Negative Moments of the Positive Binomial Useful in Life Testing." *Technometrics* 2: 227-42; May 1960.

MICHAEL, WILLIAM B. "An Overview of the Symposium." *Educational and Psychological Measurement* 18: 455-61; Autumn 1958.

MITRA, SUJIT KUMAR. "On the Limiting Power Function of the Frequency Chi-Square Test." *Annals of Mathematical Statistics* 29: 1221-33; December 1958.

MOORE, PETER G. *Principles of Statistical Techniques*. New York: Cambridge University Press, 1958. 239 p.

OSTLE, BERNARD, and STECK, GEORGE P. "Correlation Between Sample Means and Sample Ranges." *Journal of the American Statistical Association* 54: 465-71; June 1959.

QUENOUILLE, MAURICE H. *Fundamentals of Statistical Reasoning*. Griffin's Statistical Monographs and Courses, No. 3. London: Charles Griffin & Co., 1958. New York: Hafner Publishing Co., 1958. 169 p.

RAMASUBBAN, T. A. "The Mean Difference and the Mean Deviation of Some Discontinuous Distributions." *Biometrika* 45: 549-56; December 1958.

RAMASUBBAN, T. A. "The Generalized Mean Differences of the Binomial and Poisson Distributions." *Biometrika* 46: 223-29; June 1959.

RAO, C. RADHAKRISHNA. "Some Statistical Methods for Comparison of Growth Curves." *Biometrics* 14: 1-17; March 1958.

RESNIKOFF, GEORGE J., and LIEBERMAN, GERALD J. *Tables of the Non-Central t-Distribution*. Stanford, Calif.: Stanford University Press, 1957. 389 p.

RIDER, PAUL R. "The Midrange of a Sample as an Estimator of the Population Midrange." *Journal of the American Statistical Association* 52: 537-42; December 1957.

RIDER, PAUL R. "Variance of the Median of Samples from a Cauchy Distribution." *Journal of the American Statistical Association* 55: 322-23; June 1960. (a)

RIDER, PAUL R. "Variance of the Median of Small Samples from Several Special Populations." *Journal of the American Statistical Association* 55: 148-50; March 1960. (b)

RIORDAN, JOHN. *An Introduction to Combinatorial Analysis*. New York: John Wiley & Sons, 1958. 244 p.

ROYCE, JOSEPH R. "The Development of Factor Analysis." *Journal of General Psychology* 58: 139-64; April 1958.

RUBEN, HAROLD. "On the Distribution of the Weighted Difference of Two Independent Student Variables." *Journal of the Royal Statistical Society* (Series B, Methodological) 22: 188-94; No. 1, 1960.

SANKARAN, MUNUSWAMY. "On the Non-Central Chi-Square Distribution." *Biometrika* 46: 235-37; June 1959.

SCHAIE, K. WARNER. "Tests of Hypotheses about Differences between Two Intercorrelation Matrices." *Journal of Experimental Education* 26: 241-45; March 1958.

SCHEFFÉ, HENRY. *The Analysis of Variance*. New York: John Wiley & Sons, 1959. 477 p.

SIMON, HERBERT A. *Models of Man: Social and Rational*. New York: John Wiley & Sons, 1957. 287 p.

SLOAN, ROBERT W. *An Introduction to Modern Mathematics*. Englewood Cliffs, N.J.: Prentice-Hall, 1960. 73 p.

STANLEY, JULIAN C. "Kimmel's 'General Case' for the Relationship between Chi-Square and Size of Sample." *Psychological Reports* 3: 344; September 1957.

STEEL, ROBERT G. D., and TORRIE, JAMES H. *Principles and Procedures of Statistics*. New York: McGraw-Hill Book Co., 1960. 481 p.

STEPHAN, FREDERICK F., and MCCARTHY, PHILIP J. *Sampling Opinions: An Analysis of Survey Procedures*. New York: John Wiley & Sons, 1958. 451 p.

TUCKER, LEDYARD R. "Determination of Parameters of a Functional Relation by Factor Analysis." *Psychometrika* 23: 19-23; March 1958.

TUKEY, JOHN W. "On the Comparative Anatomy of Transformations." *Annals of Mathematical Statistics* 28: 602-32; September 1957.

TURNER, MALCOLM E. "On Heuristic Estimation Methods." *Biometrics* 16: 299-301; June 1960.

VON MISES, RICHARD, and GEIRINGER, HILDA. *Probability, Statistics, and Truth.* Second revised English edition. New York: Macmillan Co., 1957. 244 p.

WILLIAMS, EVAN J. "The Comparison of Regression Variables." *Journal of the Royal Statistical Society* (Series B, Methodological) 21: 396-99; No. 2, 1959. (a)

WILLIAMS, EVAN J. *Regression Analysis.* New York: John Wiley & Sons, 1959. 214 p. (b)

WRIGHT, E. MURIEL; MANNING, WINTON H.; and DUBOIS, PHILIP H. "Determinants in Multivariate Correlation." *Journal of Experimental Education* 27: 195-202; March 1959.

CHAPTER V

Research Tools: Access to the Literature of Education

MARGARET R. SHEVIAK and HAYNES MCMULLEN

THIS CHAPTER is a sequel to "Research Tools: Library Resources" by Pierstorff (1957) in this REVIEW. There have been no startling changes during the last three years in the bibliographical apparatus for obtaining access to the main body of educational literature, but two trends are likely to be of considerable interest in the future. The first is the increasing amount of information available about educational systems outside the United States; the second is the development of machines and systems of searching which permit quick access to ideas and combinations of ideas not easily located through conventional bibliographies, indexes, or abstracts.

This chapter will discuss first the newer conventional bibliographical and reference aids which are primarily useful in the study of education in the United States; then the aids which are mainly useful in international studies; and, finally, the literature on systems for the mechanical indexing and searching of literature. Cumulative bibliographies which were discussed in Pierstorff's article and which are continuing without change are not considered here.

General Guides to Library Resources

Winchell (1960) completed a third supplement to her annotated guide to general reference works, and Barton (1959) prepared a fourth revision of her briefer bibliographical guide to reference books. Walford (1959) edited a comprehensive guide to reference books and bibliographies with emphasis on current material and on material published in Great Britain. Another comprehensive and detailed bibliography of basic reference works prepared by Murphey (1958) is especially well adapted for general use, because it is arranged from the viewpoint of the nonspecialist, its terminology is nontechnical, and it offers guidance in the mechanics of research and in the preparation and style of research papers.

The compilation of doctoral dissertations in the *Index to American Doctoral Dissertations* (1956, 1957, 1958, 1959) served the dual purpose of continuing *Doctoral Dissertations* compiled by Trotier and Harman and indexing dissertations abstracted in *Dissertation Abstracts*. The form and features of the previous volumes sponsored by the Association of Research Libraries have been retained in the main. A serious omission in the 1958-59 *Index* was lack of a page reference to the place in the volume where a dissertation was abstracted.

A selective list of the major abstracting journals and bibliographies for each of the social sciences was compiled by Clarke (1959). Fellows (1957) included 167 items in his guide to periodical publications intended as an aid to the study of current developments in the social sciences.

The General Field of Education

Alexander and Burke's fourth edition (1958) of their valuable aid to the researcher lists many changes in sources for the location of educational information. A full index facilitates finding a reference for which the researcher remembers only the popular title or the author. Napier (1958) provided a shorter descriptive list of sources, with emphasis on British publications.

The second edition of Good's *Dictionary of Education* (1959) contributed to a solid base of educational vocabulary. The fifth edition of *Mental Measurements Yearbook* (Buros, 1959) covers the years 1952-58. The *Encyclopedia of Educational Research* (Harris, 1960) appeared in a third edition under new editorial direction, with a number of new contributors. Contributors to earlier editions developed new treatments of their topics. The results of a symposium on important aspects of current educational research were presented by Phi Delta Kappa (Banghart, 1960).

Two continuing bibliographies mentioned by Pierstorff changed title or editorial direction. *Education in Lay Magazines* (National Education Association, 1957, 1958, 1959, 1960) ended with No. 2, 1960, and was continued as *Magazine Report*. The annual bibliography of master's theses that had been compiled by Lamke and Silvey (1957, 1958) appeared with Silvey (1959) as sole editor.

Special Fields in Education

Eells (1959a) presented an annotated bibliography of books and periodical articles devoted to college teachers and college teaching methods, which included studies appearing in periodicals, as well as published and unpublished theses. "Index B" separately lists the doctoral dissertations in these areas. Scates and Ellis (1957, 1958, 1959) also provided a bibliography of the same matter.

Mezirow and Berry (1960) compiled a comprehensive guide to articles, government publications, pamphlets, and books in major areas of liberal adult education, abstracting most items. It covers publications from the United States, Great Britain, and Canada since the end of World War II.

A series of annual bibliographies of reports on research (articles and theses) in health, physical education, and recreation was begun by Hubbard and Weiss (1959, 1960). The theses were abstracted by the institutions at which they were written. Hilton and Fairchild (1960) and

Forrester (1958) revised earlier compilations of guidance and occupational literature.

Psychology

An annotated list of reference books and a list of psychological journals were included in Daniel and Louttit's guide for researchers in psychology (1953). The book surveys psychological literature and provides technical and stylistic aids to scientific reporting. An appendix includes sources for books, tests, apparatus, equipment, and supplies. English and English (1958) produced a compact dictionary of terms used in psychology, as well as some from mathematics, medicine, and psychoanalysis.

Directories

The *Directory of University Research Bureaus and Institutes* (1960) identifies and describes current research programs in institutions of higher learning in the United States and Canada. It includes bureaus, institutes, experiment stations, laboratories, and other research organizations which are sponsored by colleges and universities, established on a permanent basis, and carrying on continuing research programs. Appendixes list university presses and members of the National Council of University Research Administrators, and indexes provide location by name of institution and geographic area.

Ash (1958) compiled a guide to special book collections with subject emphasis as reported by university, college, public, and special libraries in the United States and Canada. The *Association Index* (1958) records —by author, title, and subject—directories, yearbooks, and periodicals listing nongovernmental associations.

Education Outside the United States

The most significant of recently published aids to the study of education outside the United States is UNESCO's monumental volume on primary education (1958), the second in its *World Survey of Education* series. For each country, it contains a monograph, usually complete with tables, charts, bibliography, and glossary, with some information about the past and much about the present status of education, predominantly but not exclusively elementary education. The two latest editions of UNESCO's *Basic Facts and Figures* (1959a, 1960a) have been in English; some earlier editions were in French and Spanish. About a fourth of the tables in the latest volume are on education.

UNESCO was responsible for two helpful directories, one giving brief information about educational associations in many countries (1959c)

and the other giving full information about clearinghouses and documentation centers throughout the world (1957).

Of bibliographies of international education, the most comprehensive is an annotated volume begun by Heath (1957, 1958) of the Division of International Educational Relations in the U.S. Department of Health, Education, and Welfare, Office of Education (1959). UNESCO published a partly annotated list of texts (1960b) on research methods and, for each of several countries, references to review articles summarizing educational research, bibliographies of research, and the names of journals which regularly contain reports on research. Eells's long list (5700 items) of American theses on education outside the United States and on the education of foreigners within the United States (1959a) contains no annotations but helps identify elusive sources of information. The part of this list about scientific and mathematical education in foreign countries was issued separately (1959b). UNESCO published another specialized bibliography which lists books, journals, and articles on technical and vocational education in several regions and many countries (1959b).

Literature Searches by Mechanical Means

Most methods and machines used by industrial firms and government agencies to search scientific and technical literature are completely adaptable to searching educational literature. One unfamiliar with the subject should prepare himself with a glossary; the latest and best is Wagner's (1960). No single book, journal, or index, however, suffices as an introduction to this rapidly expanding field of technology. A survey of many systems now in use and experiments in progress was given by papers presented at two symposiums and edited by Shera, Kent, and Perry (1957) and Boaz (1959).

Advances in methods for the mechanical searching of literature are described in *Scientific Information Notes* (1959); 58 systems now in operation were described more fully in two pamphlets in the series, *Nonconventional Technical Information Systems in Current Use,* compiled by Berry (1958a) and by Henderson and Ripple (1959b). Experimental progress is described in *Current Research and Development in Scientific Documentation* compiled by Berry (1958b), by Berry and Haksteen (1958), and by Henderson and Ripple (1959a, 1960). The latest issue contains notes, averaging a page in length, about more than a hundred projects. Some of these operational and experimental systems are described more fully in such periodicals as *American Documentation* (1950 ———), which also carries abstracts of articles appearing in other journals.

Most systems for literature retrieval involve the use of statistical machinery or computers. Many educational research workers are likely to be interested in less elaborate and less expensive systems designed to

index collections of 10,000 items or less. Marginal punch cards have been in use for many years and are adequate for bibliographical control of small collections of articles or reports. One of the many descriptions of applications of punch cards for indexing, Milne and Milne's (1959) article revealed errors made in designing a system which used about 4500 cards.

Soper (1955) described an unusual system of superimposed coding called co-ordinate indexing. It allows greater flexibility and precision than most systems and is adaptable to both manual and machine use. Its application to the indexing of a small collection of articles was described by Wilkinson (1959), and its capabilities were explored in detail by Taube and associates (1953, 1954, 1956, 1957, 1958). Zatocoding, a relatively simple system in which a machine sorts marginal punched cards, was described by Shera, Kent, and Perry (1957) and in detail by Mooers (1956).

Among descriptions of applications of computers and similar machines to literature searching, the series of articles by Faden (1959a, b, c, d) is helpful in summarizing information up to the programing stage. Machine translation, not yet of much concern in education, may become more consequential. Delavenay (1960) gave a unified and understandable account of progress to the end of 1958. The most satisfactory index for material in this field is the *Applied Science & Technology Index* (1960 ——), which covers material from 1959 to the present.

Summary

During the last three years, access to the literature of education has been facilitated by a continuing stream of new bibliographies and guides, including new editions of standard works. Bibliographies appeared in the fields of adult education and health, physical education, and recreation. A variety of statistical and bibliographical works on international aspects of education have rolled from the presses of UNESCO. And, if all these guides prove inadequate, the researcher can turn to one of many mechanical aids.

Bibliography

ALEXANDER, CARTER, and BURKE, ARVID J. *How To Locate Educational Information and Data.* Fourth edition. New York: Bureau of Publications, Teachers College, Columbia University, 1958. 419 p.

American Documentation, quarterly, Interscience Publishers, New York, New York, 1950 ——.

Applied Science & Technology Index. (Edited by Roberta Purdy.) New York: H. W. Wilson Co., 1960 ——.

ASH, LEE, compiler. *Subject Collections.* New York: R. R. Bowker Co., 1958. 476 p.

Association Index; A Source-List of Directories and Other Publications Listing Associations. Los Angeles: Metropolitan Research Co. (Box 5345, Metropolitan Station), 1958. 122 p.

BANGHART, FRANK W., editor. *First Annual Symposium on Educational Research.* Bloomington, Ind.: Phi Delta Kappa (Eighth Street and Union Avenue), 1960. 112 p.

BARTON, MARY N., compiler. *Reference Books; A Brief Guide for Students and Other Users of the Library.* Fourth edition. Baltimore: Enoch Pratt Free Library, 1959. 117 p.

BERRY, MADELINE M., compiler. *Nonconventional Technical Information Systems in Current Use.* U.S. National Science Foundation, Office of Science Information Service, No. 1. Washington, D.C.: Superintendent of Documents, Government Printing Office, January 1958. 43 p. (a)

BERRY, MADELINE M., compiler. *Current Research and Development in Scientific Documentation.* U.S. National Science Foundation, Office of Science Information Service, No. 2. Washington, D.C.: Superintendent of Documents, Government Printing Office, April 1958. 54 p. (b)

BERRY, MADELINE M., and HAKSTEEN, BARBARA, compilers. *Current Research and Development in Scientific Documentation.* U.S. National Science Foundation, Office of Science Information Service, No. 3. Washington, D.C.: Superintendent of Documents, Government Printing Office, October 1958. 76 p.

BOAZ, MARTHA T., editor. *Modern Trends in Documentation.* New York: Pergamon Press, 1959. 103 p.

BUROS, OSCAR K., editor. *Fifth Mental Measurements Yearbook.* Highland Park, N.J.: Gryphon Press, 1959. 1292 p.

CLARKE, JACK A., compiler. *Research Materials in the Social Sciences.* Madison: University of Wisconsin Press, 1959. 42 p.

DANIEL, ROBERT S., and LOUTTIT, C. M. *Professional Problems in Psychology.* Englewood Cliffs, N.J.: Prentice-Hall, 1953. 416 p.

DELAVENAY, EMILE. *An Introduction to Machine Translation.* New York: Frederick A. Praeger, 1960. 144 p.

Directory of University Research Bureaus and Institutes. First edition. Detroit: Gale Research Co. (Book Tower), 1960. 199 p.

EELLS, WALTER C., compiler. *American Dissertations on Foreign Education; Doctor's Dissertations and Master's Theses Written at American Universities and Colleges Concerning Education or Educators in Foreign Countries and Education of Groups of Foreign Birth or Ancestry in the U. S., 1884-1958.* Washington, D.C.: National Education Association, Committee on International Relations, 1959. 300 p. (a)

EELLS, WALTER C. "American Doctoral Dissertations on Scientific and Mathematical Education in Foreign Countries." *Science Education* 43: 274-75; April 1959. (b)

ENGLISH, HORACE B., and ENGLISH, AVA C. *Comprehensive Dictionary of Psychological and Psychoanalytical Terms.* New York: Longmans, Green & Co., 1958. 594 p.

FADEN, B. R. "Information Retrieval on Automatic Data Processing Equipment." *Special Libraries* 50: 162-65; April 1959. (a)

FADEN, B. R. "Information Retrieval: Punched Card Equipment." *Special Libraries* 50: 197-200; May-June 1959. (b)

FADEN, B. R. "Information Retrieval: Punched Card Techniques and Special Equipment." *Special Libraries* 50: 244-49; July-August 1959. (c)

FADEN, B. R. "Information Retrieval: General Purpose Data Processing Systems." *Special Libraries* 50: 392-97; October 1959. (d)

FELLOWS, ERWIN W. "Current Bibliographic Services in the Social Sciences." *American Documentation* 8: 153-67; July 1957.

FORRESTER, GERTRUDE, compiler. *Occupational Literature; An Annotated Bibliography.* New York: H. W. Wilson Co., 1958. 603 p.

GOOD, CARTER V., editor. *Dictionary of Education.* Second edition. New York: McGraw-Hill Book Co., 1959. 676 p.

HARRIS, CHESTER W., editor. *Encyclopedia of Educational Research.* Third edition. New York: Macmillan Co., 1960. 1564 p.

HEATH, KATHRYN G., compiler. *Bibliography: 1956 Publications in Comparative and International Education.* U.S. Department of Health, Education, and Welfare, Office of Education, Division of International Educational Relations, Studies in Comparative Education. Washington, D.C.: Superintendent of Documents, Government Printing Office, 1957. 47 p.

HEATH, KATHRYN G., compiler. *Bibliography: 1957 Publications in Comparative and International Education.* U.S. Department of Health, Education, and Welfare, Office of Education, Division of International Educational Relations, Studies in Comparative Education. Washington, D.C.: Superintendent of Documents, Government Printing Office, 1958. 97 p.

HENDERSON, MADELINE M., and RIPPLE, NANCY, compilers. *Current Research and Development in Scientific Documentation.* U.S. National Science Foundation, Office of Science Information Service, No. 5. Washington, D.C.: Superintendent of Documents, Government Printing Office, October 1959. 102 p. (a)

HENDERSON, MADELINE M., and RIPPLE, NANCY, compilers. *Nonconventional Technical Information Systems in Current Use.* U.S. National Science Foundation, Office of Science Information Service, No. 2. Washington, D.C.: Superintendent of Documents, Government Printing Office, September 1959. 66 p. (b)

HENDERSON, MADELINE M., and RIPPLE, NANCY, compilers. *Current Research and Development in Scientific Documentation.* U.S. National Science Foundation, Office of Science Information Service, No. 6. Washington, D.C.: Superintendent of Documents, Government Printing Office, May 1960. 130 p.

HILTON, MARTHA E., and FAIRCHILD, ELLEN P., editors. *Guide to Guidance: A Selected Bibliography of 1959 Publications of Interest to Deans, Counselors, Advisors, Teachers, and Administrators.* Syracuse, N.Y.: Syracuse University Press, 1960. 44 p.

HUBBARD, ALFRED W., and WEISS, RAYMOND A., compilers. *Completed Research in Health, Physical Education, and Recreation.* Washington, D.C.: American Association for Health, Physical Education, and Recreation, a department of the National Education Association, 1959. Vol. 1, 60 p.

HUBBARD, ALFRED W., and WEISS, RAYMOND A., compilers. *Completed Research in Health, Physical Education, and Recreation.* Washington, D.C.: American Association for Health, Physical Education, and Recreation, a department of the National Education Association, 1960. Vol. 2, 76 p.

Index to American Doctoral Dissertations, 1955-56. Ann Arbor, Mich.: University Microfilms, 1956. 171 p.

Index to American Doctoral Dissertations, 1956-57. Ann Arbor, Mich.: University Microfilms, 1957. 209 p.

Index to American Doctoral Dissertations, 1957-58. Ann Arbor, Mich.: University Microfilms, 1958. 182 p.

Index to American Doctoral Dissertations, 1958-59. Ann Arbor, Mich.: University Microfilms, 1959. 200 p.

LAMKE, T. A., and SILVEY, HERBERT M., editors. *Master's Theses in Education, 1956-57.* Cedar Falls, Iowa: Research Publications, 1957. 188 p.

LAMKE, T. A., and SILVEY, HERBERT M., editors. *Master's Theses in Education, 1957-58.* Cedar Falls, Iowa: Research Publications, 1958. 170 p.

MEZIROW, JACK D., and BERRY, DOROTHEA, compilers. *Literature of Liberal Adult Education, 1945-1957.* New York: Scarecrow Press, 1960. 308 p.

MILNE, LORUS J., and MILNE, MARGERY. "Foresight and Hindsight on a Punch-Card Bibliography." *American Documentation* 10: 78-84; January 1959.

MOOERS, CALVIN N. "Zatocoding and Developments in Information Retrieval." *ASLIB Proceedings* (Association of Libraries and Information Bureaux, London) 8: 3-22; February 1956.

MURPHEY, ROBERT W. *How and Where To Look It Up: A Guide to Standard Sources of Information.* First edition. New York: McGraw-Hill Book Co., 1958. 721 p.

NAPIER, IRIS H. "Basic Reference Material in Education." *Library World* 59: 126-30; March 1958.

NATIONAL EDUCATION ASSOCIATION, RESEARCH DIVISION and AMERICAN ASSOCIATION OF SCHOOL ADMINISTRATORS. *Education in Lay Magazines.* Educational Research Service Circulars. Washington, D.C.: the Association, 1957. No. 7, 20 p.

NATIONAL EDUCATION ASSOCIATION, RESEARCH DIVISION and AMERICAN ASSOCIATION OF SCHOOL ADMINISTRATORS. *Education in Lay Magazines.* Educational Research Service Circulars. Washington, D.C.: the Association, 1958. No. 1, 28 p. No. 4, 36 p. No. 7, 30 p. No. 8, 22 p.

NATIONAL EDUCATION ASSOCIATION, RESEARCH DIVISION and AMERICAN ASSOCIATION OF SCHOOL ADMINISTRATORS. *Education in Lay Magazines.* Educational Research Service Circulars. Washington, D.C.: the Association, 1959. No. 2, 28 p. No. 3, 26 p. No. 5, 18 p. No. 8, 19 p.

NATIONAL EDUCATION ASSOCIATION, RESEARCH DIVISION and AMERICAN ASSOCIATION OF SCHOOL ADMINISTRATORS. *Education in Lay Magazines.* Educational Research Service Circulars. Washington, D.C.: the Association, 1960. No. 2, 22 p.

PIERSTORFF, LOLA R. "Research Tools: Library Resources." *Review of Educational Research* 27: 471-75; December 1957.

SCATES, DOUGLAS E., and ELLIS, HELEN C., compilers. "Doctoral Studies in Teacher Education, 1955-56." *Journal of Teacher Education* 8: 318-27; September 1957.

SCATES, DOUGLAS E., and ELLIS, HELEN C., compilers. "Doctoral Studies on the Education of Teachers and Administrators, 1956-57." *Journal of Teacher Education* 9: 317-26; September 1958.

SCATES, DOUGLAS E., and ELLIS, HELEN C., compilers. "Doctoral Studies on the Education of Teachers and Administrators, 1957-58." *Journal of Teacher Education* 10: 366-75; September 1959.

Scientific Information Notes (formerly *Science Information News*), bimonthly, U.S. National Science Foundation, Superintendent of Documents, Government Printing Office, Washington, D.C., 1959 ——.

SHERA, JESSE H.; KENT, A.; and PERRY, J. W. *Information Systems in Documentation.* New York: Interscience Publishers, 1957. 639 p.

SILVEY, HERBERT M., editor. *Master's Theses in Education, 1958-59.* Cedar Falls, Iowa: Research Publications, 1959. 177 p.

SOPER, ALAN K. "Some Observations on the Use of Punched Cards for a Personal Information File." *ASLIB Proceedings* (Association of Libraries and Information Bureaux, London) 7: 251-58; November 1955.

TAUBE, MORTIMER, and ASSOCIATES. *Studies in Coordinate Indexing.* Washington, D.C.: Documentation Inc., 1953. Vol. 1, 110 p.

TAUBE, MORTIMER, and ASSOCIATES. *Studies in Coordinate Indexing.* Washington, D.C.: Documentation Inc., 1954. Vol. 2, 111 p.

TAUBE, MORTIMER, and ASSOCIATES. *Studies in Coordinate Indexing.* Washington, D.C.: Documentation Inc., 1956. Vol. 3, 165 p.

TAUBE, MORTIMER, and ASSOCIATES. *Studies in Coordinate Indexing.* Washington, D.C.: Documentation Inc., 1957. Vol. 4, 129 p.

TAUBE, MORTIMER, and ASSOCIATES. *Studies in Coordinate Indexing.* Washington, D.C.: Documentation Inc., 1958. Vol. 5, 178 p.

UNESCO. *Education Clearing Houses and Documentation Centres: A Preliminary International Survey.* Educational Studies and Documents, No. 22. Paris: United Nations Educational, Scientific, and Cultural Organization, 1957. 65 p.

UNESCO. *World Survey of Education: II. Primary Education.* Paris: United Nations Educational, Scientific, and Cultural Organization, 1958. 1387 p.

UNESCO. *Basic Facts and Figures; International Statistics Relating to Education, Culture, and Mass Communication, 1958.* Paris: United Nations Educational, Scientific, and Cultural Organization, 1959. 142 p. (a)

UNESCO. *An International Bibliography of Technical and Vocational Education.* Educational Studies and Documents, No. 31. Paris: United Nations Educational, Scientific, and Cultural Organization, 1959. 72 p. (b)

UNESCO. *An International Directory of Education Associations.* Educational Studies and Documents, No. 34. Paris: United Nations Educational, Scientific, and Cultural Organization, 1959. 91 p. (c)

UNESCO. *Basic Facts and Figures; International Statistics Relating to Education, Culture, and Mass Communication, 1959.* Paris: United Nations Educational, Scientific, and Cultural Organization, 1960. 198 p. (a)

UNESCO. "Educational Research: Selected Reports, Books on Methodology, Bibliographies, and Journals." *Education Abstracts* 12: 1-25; May-June 1960. (b)

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, OFFICE OF EDUCATION, DIVISION OF INTERNATIONAL EDUCATIONAL RELATIONS. *Bibliography: 1958 Publications in Comparative and International Education.* Studies in Comparative Education. Washington, D.C.: Superintendent of Documents, Government Printing Office, 1959. 111 p.

WAGNER, FRANK S., JR. "A Dictionary of Documentation Terms." *American Documentation* 11: 102-19; April 1960.

WALFORD, ARTHUR J. *A Guide to Reference Material.* London: Library Association, 1959. 543 p.

WILKINSON, WILLIAM A. "Indexing a Personal Reference File." *Special Libraries* 50: 16-18; January 1959.

WINCHELL, CONSTANCE M. *Guide to Reference Books.* Seventh edition. Third supplement, 1956-1958. Chicago: American Library Association, 1960. 145 p.

Additional References

EELLS, WALTER C., compiler. *College Teachers and College Teaching: An Annotated Bibliography on College and University Faculty Members and Instructional Methods.* Atlanta, Ga.: Southern Regional Education Board (130 Sixth Street, N.W.), July 1957. 282 p. Supplement, June 1959, 134 p.

HENDERSON, MADELINE M., compiler. *Current Research and Development in Scientific Documentation.* U.S. National Science Foundation, Office of Science Information Service, No. 4. Washington, D.C.: Superintendent of Documents, Government Printing Office, April 1959. 85 p.

CHAPTER VI

Research Tools: Observing and Recording Behavior

JOHN WITHALL

IT APPEARS THAT, at long last, researchers have taken to heart the dictum credited to Kurt Lewin that there is nothing so practical as a good theory. Some research reported gives distinct signs of having been guided by implicit theories or models. The theories are by no means full-blown but seem to be in the process of development and formulation. The upshot is that some, though not all, of the research activity noticed here has been conducted within a framework that is sociopsychologically oriented and process oriented.

What might be called, after Jahoda, the multiple-criterion approach seems to be implicit in some theories. Educational researchers appear to have arrived at the point with respect to instruction that Jahoda (1958) has arrived at with respect to the concept *mental health*, namely, that a multiple-criterion approach is needed to better understand, control, and predict variables in these global phenomena. The current thinking seems to be that these all-encompassing and relatively meaningless concepts have to be broken down into manageable, discrete, describable operations or behaviors. This, in connection with instruction, necessitates the specifying, describing, and quantifying of the behaviors of teachers and learners under defined and described conditions.

This chapter (a) offers a brief historical backdrop to current efforts at identifying, assessing, and quantifying teacher-learner interactions in the classroom; (b) identifies some of the major studies that have developed methods and instruments for observing and recording classroom behaviors; and (c) indicates the directions in which present trends in research seem to point.

Backdrop to Current Research

Research on teachers and learners in the classroom has moved in stages. At the outset, with a nod toward learners as if they were all of the same mold, there was the listing of teacher traits by supervisors and administrators and sometimes pupils. Next came the stage of identification of words or phrases that teachers used which appeared to bear on the behavior and quality of learning. Another was that of studying child growth and development to better understand what went on in the educative process and to give some guidelines for classroom procedure. This tack tended to displace and cast into disrepute the *tabula rasa* concept in the learning relationship. There followed a sociometric-analysis stage, when individuals were seen as members of a social group in the

learning situation. Finally, the findings of social psychology were utilized, and researchers studied classes of pupils as groups and analyzed the interaction of the participants in this social milieu with particular attention to the role and functions of both teacher and learners in the educational process.

Melby wrote in 1936: "One interesting outcome of the application of the various techniques for analyzing and describing classroom procedures seems to be the general disappointment with the conditions they reveal [which] tend to show an enormous lag between our theory and practice in education. . . ." This stricture seems to be as relevant today as it was 25 years ago. We have just begun to develop some bench marks in our efforts to assess, measure, and make predictions about classroom learning and teaching, with the help of other disciplines, especially social psychology, anthropology, and sociology. These have afforded us some guides to identification and analysis of classroom variables that influence learning. Some of these, which may be subsumed under the rubric of group influences, include the feelings and perceptions of learners and teachers; the roles which teachers and learners take in the classroom; the interpersonal interactions of teachers with learners and learners with learners; and the influence of the peer culture and of social class and differing cultures, along with the pervasive influence of values and value systems.

Dewey's theories of learning and his philosophy of education are supposed to have helped educators conspicuously to conceptualize the learning process as one in which the learner plays a major role, where problem-solving techniques are a major vehicle of learning, and where self-guided, functional, pragmatic learning eventuates. If Dewey's operationalism is a guiding tenet in today's schools—and Dewey is generally held responsible for the *emasculation* of our educational system, in terms of lowered academic standards, cavalier treatment of subject-matter mastery, and decline of the mental discipline—it would take some doing to demonstrate that this is so in the light of what is taking place today. For the ways in which teachers teach and the manner in which educational researchers have gone about their research indicates that until quite recently there has been incomplete understanding of the pragmatism, operationalism, problem solving, and self-directed activity for which Dewey is held responsible.

It is astonishing and discouraging, as one examines the research of the past and the near-present, to discover how little attention, relatively, has been paid to the major variables in the teaching-learning process—the teacher, the learner, and teacher-learner interaction. Until recently, researchers have consistently concentrated on the influence of such matters as personality traits of teachers, spaced periods of learning as opposed to concentrated periods of learning, individualized versus mass instruction, lecture versus discussion techniques in the classroom, and audio-visual aids and their contributions to the learning process. No one would have denied the fact that the teacher (as well as the learner) was an

important factor, but it was assumed that the teacher's own unique impact and influence could be taken as a given factor, just as learners had been perceived as similar if not identical entities in the past.

Social psychology gave increasing emphasis to leadership on the part of the teacher and to the impact of the group and its social-emotional climate on the roles and behaviors of teachers and learners and on the life pattern and achievement of each learner. These focuses of concern lately have been accompanied by interest on the part of educators and educational researchers in the influence of group experiences and activities on learning in the classroom and also on intergroup education and intercultural relations. The insights derived from group therapy were also related to educational procedures and problems. Sometimes they appeared in life-adjustment education, and most recently they emerged in the principle that the individual's personal-social needs must be met before he can marshal his problem-solving skills and fulfill his responsibilities for content mastery.

Historical Perspective

As historical background for examination of current attempts to develop techniques and instruments for observing and recording teacher and learner behaviors in the classroom, the major studies since 1930 are cited.

One of the earliest attempts to devise a procedure for examining specific teacher behaviors in the learning situation was Johnson's (1935) study of the teacher's verbal directions to children aged three to seven. She found that explicit directions or requests to individuals given in an unhurried, positive, and encouraging manner ensured much greater success in performance than vague, hurried, and discouraging verbal directions. Olson and Wilkinson (1938) found teaching effectiveness related to the amount of verbal control in the classroom which could be described as positive and directing. The teachers who used blanket and generalized statements were less efficient teachers. The more able teachers used a larger proportion of guiding and approving statements.

Anderson and his colleagues (1939, 1945, 1946a, b), postulating that the main direction of influence is from teacher to pupil, developed teacher-behavior categories to measure this influence objectively. Anderson identified 26 categories with which he assessed teacher influence on pupils' behaviors and differentiated teachers on the basis of the relative number of integrative (sympathetic, encouraging, friendly) and dominative (deprecating, authoritarian, unfriendly) contacts they had with children. Concomitant differences in children's behavior were identified. It was demonstrated that children who were exposed to more integrative teacher behaviors showed lower frequencies of distracted and nonconforming behavior and significantly higher frequences of spontaneous, co-operative,

and self-initiated behavior. Anderson, Brewer, and Reed (1946b) said: "The ultimate objective of these several researches has been to produce measures of teachers' classroom personalities that would have practical usefulness for research workers, for school administrators, and for teachers themselves."

Lippitt (1940), in experimentally controlled group situations, assessed the impact of democratic, autocratic, and laissez-faire leadership styles on the cohesiveness of small groups of boys and on their interpersonal and problem-solving activities. In the light of Lippitt's work and Anderson's premise that the main direction of influence in the classroom is from teacher to pupils, Withall (1948, 1949) developed a seven-category instrument to assess classroom verbal behaviors of the teacher in terms of their learner-centeredness or teacher-centeredness—that is, whether the inferred intent of those verbalizations was to encourage and enhance the learning and achievement of the pupils or enhance and strengthen the goals and status of the teacher.

Flanders (1951) followed this with an investigation of the influence of experimentally induced anxiety, as evidenced and measured by increased pulse rate, galvanic skin response, and a graphic record of introspectively perceived and reported positive or negative feelings of the learners. Perkins (1951) and Glidewell (1951) pursued different and related facets of the same problem. Thelen, who guided and helped facilitate these researchers in his laboratory, has pushed further in the exploration of the sociopsychological variables influencing individual learning and group achievement.

Cornell, Lindvall, and Saupe (1953) developed an instrument to focus on eight dimensions in the classroom with particular reference to teacher-pupil interaction. The dimensions included social organization in the classroom, initiative of the pupils, competency of the teacher as indicated by differing performances in terms of selected behaviors, and classroom climate as reflected in the behavior of the pupils and as shown in the behavior of the teacher. Thirty-two classrooms were observed, and the instrument significantly discriminated among them. The authors indicated that revisions of the instrument seemed desirable and that an inventory administered to students on their perceptions of the classroom situation may be as valid as the observation device.

Hedlund (1953) developed an instrument to identify critical incidents or behaviors which enable principals, educational experts, and pupils to distinguish effective and ineffective teachers. Some 4600 descriptions of effective and ineffective behaviors by teachers were reported. They fell into 68 specific behavior categories. After considerable sifting, winnowing, and testing, 43 behavior items emerged with strong predictive value, some useful for both sexes and some for one sex only. Ultimately, a predictive index comprising 18 of the best predictive items for each sex was worked out. Hedlund observed that, although his findings were encouraging, they needed to be cross-validated.

Conceptual Frameworks

In accordance with the emergent sociopsychological, process-oriented, and multiple-criterion approach to the study and assessment of the teaching-learning process, Jensen (1955, 1960) identified the need for a framework of concepts that could be used to analyze classroom behaviors systematically. Taking the needs approach and examining learners both as individuals and as group members, he specified seven dimensions: problem solving, authority-leadership, power, friendship, personal prestige, sex, and privilege. He contended that class productivity, individual achievement, and member satisfaction with the class arose from the diverse relationships of the seven different dimensions, and he offered a promising framework in which to assess the influence of social interactions in the classroom and the resultant influences on group performance and individual learning. He underlined, as Jennings (1947) had done, the importance of there being a network of relationships in the learning and problem-solving group that ensure that both individual needs and group needs are satisfied so that the objective problem solving, achievement-learning, and related work tasks are dealt with effectively. Getzels and Thelen (1960) summed up prevailing opinion on a process, sociopsychological approach to classroom learning, and described nomothetic, idiographic, and transactional styles of teaching. They identified the transactional style as striking a balance between promotion of students' achieving personal goals and requirement of their mastering subject matter in the classroom situation. In their view, the most viable instructional setting is one in which both the individual's self-development goals and content-mastery goals are attained. They emphasize, moreover, that the individual's self-needs must be met before progress can be made in content mastery.

If an educational theory—that is, a systematic portrayal within an integrated framework of a number of variables to demonstrate the relationships among these variables, as well as their relationships with other factors such as knowledge, attitude, and skill outcomes—is to be formulated, then the kind of concept identification and integration which Jensen, Thelen, and Getzels have set forth in their recent writings seem to be the *sine qua non* of such theory development.

Research Influenced by a Sociopsychological Rationale

Considerable research has been done to assess the variables of the teaching-learning process from the vantage point of the developing sociopsychological framework. In such studies cognizance is taken of the interaction of personal-social and achievement-learning needs in the context of classroom instructional process. Flanders (1959, 1960a, b) focused on aspects of the transactional type of teaching—that is, on teacher be-

haviors which control and delimit the students' freedom of action as contrasted with those which invite and encourage activity and spontaneous participation by the learners. He (1960b) developed 12 categories for analysis of the influence pattern of the teacher, basing them on constructs and categories of Anderson (1939), Withall (1949), and Bales (1950). Flanders's 12-category system assesses direct and indirect influence of the teacher's talk, as well as the students' talk, according to whether it is responding to or initiating behavior. It identifies, along with other things, teachers who are parsimonious with praise and encouragement and show little interest in the affect side of the students' learning activities, and thus the system has considerable significance for the current research in the mental-health impact of teachers' classroom behaviors. Flanders's interaction analysis technique affords: (a) operational definition of teacher behaviors and (b) a way of quantifying the behaviors that contribute to the dynamic interaction of the participants in the teaching-learning process.

Damrin (1959) developed an instrument, under the name of the *Russell Sage Social Relations Test,* to measure the competence and skill of elementary-school youngsters in group planning and group work. The test, which involved three construction problems with miniature blocks, comprises a planning stage in which the group decides how to construct the figure and an operations stage in which the figure is constructed. No limit is set on the time to be used in planning, but 15 minutes is allotted to the operations stage. During both the planning and the operations stages an observer keeps a record of behavior on standard observation sheets. Some concomitant indicators of the reliability and validity of the instrument have been set forth, and work is under way to vigorously test the technique statistically. Seven types of groups emerged from the planning stage: (a) mature, (b) dependent, (c) immature, (d) semicontrolled, (e) semirestrained, (f) uncontrolled, and (g) restrained. Nine types of groups emerged from the operations stage: (a) mature, (b) immature, (c) disinterested, (d) rollicking, (e) excited, (f) rowdy, (g) suppressed, (h) bickering, and (i) quarreling.

The instrument looks promising in that it draws on sociopsychological concepts and focuses on specific, observable behaviors in terms of sociopsychological context. Drawbacks at this stage are lack of evidence regarding its validity and reliability and the necessity for two highly trained and skilled individuals to administer the test and record the subjects' behaviors. The former drawback is being dealt with, and the latter arises with the use of any worthwhile testing, observation, and recording process so far devised. The promise of the instrument lies partly in the fact that it deals with the measurement of social and psychological forces and gives evidence of being applicable to other age levels, including adults.

Gold (1958), working within the framework of an interactional theory of leadership, examined the learning situation to determine what variables influence the status and roles of children in the classroom. He used the

concepts of power, properties (attributes or qualities), and resources (abilities valued by the peer group) possessed by children to analyze the social relationships of those youngsters in classroom groups from kindergarten through grade 6. Seventeen characteristics of children deemed important by their peers were identified. These included such characteristics as "smart at school," "acts friendly," "knows how to act so people will like him," and "does things for you." Pupils were asked to assign these traits to others in their class. The results of the study indicated ". . . a relationship between the values of the children in our study, the properties perceived to be possessed by the children and the power structure of the classroom group. . . ."

This study placed considerable emphasis on the peer-group influences in the learning situation which, it cannot be denied, exerted considerable influence on the child's status in the classroom. It also seems clear that the peer-group values of children influence their openness to learning content, attitudes, and skills. In many respects the pupils with power serve as gatekeepers to the learning of the knowledge the teacher is trying to impart. This emphasis on peer-group influence in the learning situation underlies its role as an instructional vehicle.

Zander and Van Egmond (1958) examined the relationship of intelligence and social power (ability to get others to do things) of 418 children in grade 2 and grade 5 classrooms. They hypothesized that the cultural expectations for boys to be self-reliant and to strive for achievement were easily realized if the boy possessed either social power or intelligence and that society's expectations for girls to be obedient, nurtural, and responsible required neither social power nor intelligence. Data included *Kuhlman-Anderson Test* scores, peers' ratings of four characteristics, observed behavior in small work groups, and teachers' ratings of seven social behaviors. The findings were that: (a) social power is not highly correlated with intelligence; (b) those with greater social power were better liked regardless of sex; (c) boys won social power by being threatening, and girls by doing well the things required of them; (d) boys low in social power and intelligence were like girls in their quiet, unassertive patterns of behavior.

Shapiro, Biber, and Minuchin (1957) described an instrument, the *Cartoon Situations Test*, developed for the purpose of predicting teaching success. The dimensions assessed by the instrument include the prospective teachers' quality of expressive tone, orientation to dilemmas, quality of emotional identification with characters in the cartoon, perception of the authority role, quality of psychological thinking, orientation to action, mode of aggressive expression, and attitude toward socialization. The kind of affect projected into the cartoon situation seemed crucial, as did the absence of expression of hostility. The findings indicated that the instrument has predictive value; its use is being further explored.

Haigh and Schmidt (1956) examined the relative effectiveness of teacher-centered and group-centered classes. Students were placed in

teacher-centered and group-centered classes according to their stated preferences. The group-centered class was not required to take a final examination. The *Horrocks-Troyer Test* was given to all subjects at the end of the experiment, which ran one academic year. There appeared to be no significant differences between the two groups in subject-matter learning.

Maier and Maier (1957) compared the effects of two leadership-discussion techniques on group decision. One technique afforded free discussion in a permissive manner; the other entailed the leader's breaking a problem into parts and keeping all group members together in considering it. A significant difference was obtained in the quality of decisions of the two groups: twice as many of the developmental discussion group members as the free discussion group members reached a high-quality decision. The generalizability of these results is limited; the authors believe their findings applicable only to problem solving in which there is little or no emotional involvement.

Calvin, Hoffman, and Hard[illegible]957) tested the hypothesis that a permissive social climate enhan[illegible]h achievement of high-IQ subjects and handicaps subjects with onl[illegible]verage intelligence scores. Their conclusion, reached on the basis o[illegible] trend occurring in all their experiments and not on the basis of an[illegible]ptable level of statistical significance, was that findings supported [illegible]ypothesis.

These studies on th[illegible] effect of teacher-centered versus learner-centered group atmospheres and on permissive as opposed to structured teaching methodologies throw some doubt on the assumption that permissive and learner-centered instruction inevitably leads to better learning and achievement.

Getzels and Guba (1955) used a 71-item instrument that dealt with the socioeconomic, civic, and professional roles of the teacher in terms of their situational and personal aspects. They found the teachers feeling troubled at the role conflicts they experienced.

Trow (1960a, b) assessed the several functions and roles of the teacher and related them to the teacher's skill in effectively implementing the roles. He emphasized the inescapable teacher-learner relationship of controller to controlled, superior to subordinate, and the central roles of the teacher in this context as therapist, strategist, and instructor. Trow and his colleagues have consistently emphasized the sociopsychological framework for the study of the learning process in the classroom, and have pioneered some of the work and findings emerging from this framework.

A Multiple-Criterion Approach—Operational Definitions of Classroom Interaction

Hughes and associates (1959), proceeding from the assumption that the teacher cannot speak or act in the teacher-learner situation without performing a function for someone in the situation, developed a code for

the analysis of teaching. The subjects were 21 teachers judged "good" by administrators and supervisors from several schools and 10 teachers representative of one school. Focusing on the behavior of the teacher as reported by two trained observers in narrative form, Hughes identified 31 functions which the teacher fulfilled vis-à-vis specific individuals in the classroom. She examined the problem of each teacher-act's having a multi-pronged effect on pupils in a classroom. She confined herself, however, to interpreting the act as performing a function only for the particular individual or individuals to whom the act was directly addressed.

The 31 functions were subsumed under seven categories: (a) controlling, (b) imposition of teacher, (c) facilitating, (d) developing content, (e) response, (f) positive affectivity, and (g) negative affectivity. Conclusions reached were that there are few "good" and few "bad" teachers, that criteria used by administrators for judging "good" teachers are compounded of many elements and are not comparable, and that the relationship of the teacher to child reflects to a marked degree the adult-child relationship of our culture. Some conclusions were actually opinions and went beyond the data presented.

Wright (1959), studying verbal behaviors of secondary-school mathematics teachers, used three frames of reference for assessment: ability to think, appreciation of mathematics, and attitude in terms of curiosity and initiative. If the verbalization did not fall into at least two of the frames, it was categorized as neutral. The instrument appears to have several limitations: (a) the observer must be trained in the specific subject matter; (b) he must be trained only by the researcher who developed the instrument; (c) he is required to interpret and infer as he categorizes; (d) large amounts of time must be devoted to the observation of each classroom.

Medley and Mitzel (1958) developed the *Observation Schedule and Record* (*OScAR*) by modifying the classroom observational procedures of Withall (1948) and Cornell, Lindvall, and Saupe (1953). The observer records both teacher and learner behaviors under an Activity Section which identifies 44 possible activities of teacher and pupils. He next employs the Grouping Section of the instrument to identify and list large and small groups and to note acts of individual pupils. He then notes in the Materials Section the type of instructional materials used. Finally, he enters in the Signs Section items symptomatic of classroom climate. Differences between classes can be identified, it is maintained, with fewer than 14 variables. A study of the factorial structure of the 14 scoring keys indicated that the *OScAR* technique gives reliable information about three relatively discrete dimensions of classroom behavior—the social-emotional climate, the relative emphasis on verbal learnings, and the degree to which the social structure centers about the teacher.

In a subsequent study Medley and Mitzel (1959) tried to identify the relationship between some measures of teacher effectiveness and some teacher-behavior variables. They compared pupils' reading growth, prob-

lem-solving skills, pupil-teacher rapport, teachers' self-ratings, and principals' ratings with teacher behaviors associated with emotional climate, emphasis on verbal activities, and social organization. Their findings indicated that supervisors' ratings for evaluating learning are inadequate. They questioned the relevance of a considerable body of research that has used ratings of some kind as a criterion of teacher effectiveness. They also found that gains in reading and gains in group problem-solving skills seem unrelated to recorded classroom behaviors of teachers and pupils.

More studies of this sort attempting to relate learner achievements to identified behaviors in the classroom may dissuade researchers from employing designs which involve ratings to assess variables. Despite the fact that a number of studies, such as those of Brookover (1940), Jayne (1945), Lins (1946), and Anderson (1954), have indicated the questionable validity of ratings and checklists, such ratings and lists are still used as criteria, as, for example, by Willard (1957) and Davidson and Lang (1960).

Kowatrakul (1959) developed an instrument comprising six categories for studying student behaviors in the classroom. The categories are: (a) intent on ongoing work, (b) social-work oriented, (c) social-friendly, (d) momentary withdrawal, (e) intent on other academic work, and (f) intent on work in nonacademic area. These were used while the students were doing independent seatwork, watching or listening, or participating in a discussion. It was possible to identify and examine relationships between classroom activities, subject matter, and students' behaviors. The study was a modest attempt to specify, define, and quantify discrete behaviors in the classroom under certain stated conditions. By such little steps a formulation of a theory of education may eventually be reached that will help predict and control the variables of the educative process.

Kounin and Gump (1958) studied the behavior of kindergarten children as the latter watched their teacher disciplining or scolding a child for misbehavior. The researchers collected and analyzed 406 incidents and categorized the teachers' acts in terms of clarity, firmness, or roughness. A child's behavior as he watched the reprimand was listed as: (a) no reaction, (b) behavior disruption, (c) conformance, (d) nonconformance, or (e) both conformance and nonconformance. Within the framework of disciplinary procedures, it seemed that the ripple effect (impact of the teacher's disciplinary action on the watching child) is best controlled by clear instructions to the child being reprimanded. On the one hand, firmness or lack of it did not allow reliable prediction of how the watching child would react; on the other hand, roughness usually resulted in behavior disruption in the watching child. It is interesting to note that a phenomenon of which all have been aware (the effect on children of witnessing the public disciplining of a peer) has not been more closely examined. This and similar projects point to development of a sound theory of education.

Cogan (1956, 1958a, b), using perceptions and judgments of pupils as a criterion of effective teaching, deliberately rejected as criteria both pupil change and the more commonly (and easily) used evidence from in-service ratings and experts' opinions of the teacher's competence. He categorized teacher behaviors as preclusive, inclusive, and conjunctive, and assessed their effects on the learners. These effects were measured in terms of pupil performance of required and self-initiated work having to do with classroom activities. Cogan examined the logic and desirability of using pupil change as the major criterion of teacher effectiveness, but rejected it in favor of reports by the pupil of having carried out required schoolwork and self-initiated work arising from classroom experiences. This looks like a direct and common-sense way of assessing teacher effectiveness and of capitalizing on pupil judgments and perceptions which, to judge by earlier research, appear to have more reliability and validity than administrators' or supervisors' ratings.

Levin, Hilton, and Leiderman (1957) offered a survey of the main studies of the Harvard Teacher Education Research Project. They included a précis of Cogan's study and digests of the other studies, including an examination of authoritarianism in teaching, ego involvement in teaching, interests of teachers, bases for withdrawal from teaching, differences between elementary and secondary student teachers, and prediction of classroom behaviors of student teachers. They concluded with the understatement ". . . we have discovered that prediction of teacher behavior is a complex task with many questions which demand further investigation."

Rabinowitz and Rosenbaum (1958) assessed the predictive value of pupil-teacher rapport by certain standardized and some experimental instruments. The battery of instruments included the *Minnesota Teacher Attitude Inventory*, the *California I Scale*, the *Draw-a-Teacher Technique*, and the *Strong Vocational Interest Blank*. Seventeen measures comprising nine test scores, seven classroom observations, and one measure of pupil-teacher rapport were used. The researchers reported that the tests, singly or in combination with one another, failed to predict subsequent pupil-teacher rapport, and they concluded that they did not correlate with the objective measure of behavior in the classroom.

All the problems of research in this area are summed up and recorded by Ryans (1960) in an impressive, statistically comprehensive, and sophisticated manner. One of his findings confirmed the belief that teacher behavior in the classroom can be represented by three dichotomies which might be designated as friendly versus aloof, systematic versus unorganized, and imaginative versus uninspired. Results of the study derive, in the main, from use of two instruments, the *Classroom Observation Record* and the *Teacher Characteristics Schedule*. The former consists of 22 bipolarities, for example, apathetic versus alert, uncertain versus confident, partial versus fair. Eighteen of these opposites were used to rate teacher behaviors, and four were used to rate pupil behaviors. The 22 bipolarities were scaled on a seven-point scale in which the fourth

represented an average or neutral score. Observers noted specific behaviors by teachers and pupils and estimated the extent to which one or the other pole was approximated by the behavior of the teacher.

The other instrument, the *Teacher Characteristics Schedule*, comprises 300 multiple-choice and checklist items of teacher attitudes and viewpoints which seemed to correlate with teacher classroom behaviors as rated by the observers using the *Classroom Observation Record*. Ryans's summary points up the immensity of the task involved in devising ways of assessing and predicting teacher behaviors. Despite the more than 10 years of painstaking, thorough, and concentrated effort that this work represents, one is appalled at the fact that we have merely begun to nibble at the problem. This is made clear by the fact that the not inconsiderable findings of all the years of work by Ryans and his colleagues can be summarized on two pages (360 and 361) of his book. It is interesting to note that the lack of clear knowledge of the patterns of behavior of teachers cited by Ryans is being gradually eliminated by work such as that of Medley and Mitzel (1959) and Flanders (1960b).

At the University of Wisconsin in November 1960 four research projects on mental health in teacher education, supported by the National Institute of Mental Health, reported their efforts to describe and measure behavior patterns of both university instructors and public-school teachers in the classroom. Two working papers of the Wisconsin project, by Newell, Lewis, and Withall (1960) and Lewis, Withall, and Newell (1960) include statements on a 14-category instrument designed to describe teachers' behavior in terms of their asking for or giving information and directions to the learners and in terms of the negative and positive affects that accompany these interactions. Interjudge reliabilities (rank-order correlation coefficients) between two highly trained observers in three classrooms were 0.99, 0.97, and 0.98.

The University of Texas program concerned with mental health in teacher education developed recording operations in the instructional situation to describe classroom behaviors of the teacher and verbal and nonverbal behaviors of the students (Harris, 1960). Observers record in shorthand style all observable behaviors of students and teachers. Students' and instructors' oral responses are recorded verbatim. The record is transcribed to a running account as soon as possible after observation. Techniques used to analyze the typed transcripts in process of development include content analysis, categorization of specific units of content, interaction process analysis, and adaptation of case-study techniques.

The Bank Street College of Education project staff (1960) outlined the beginnings of a classroom observation procedure of their multifaceted study of the relationship of school experiences and personality development. Two recorders observe intensively for one hour and a half, and their records are combined to give the teacher's presentation and management techniques and the child's responses. The procedure aims to

reveal the two levels of social-psychological functions that appear in the classroom, the overt and the covert. This entails not only the planned, recognized, or relatively formal patterns of interaction in the classroom, but also the teacher's manner of indirectly structuring the children's orientation toward her, each other, and their work, by analyzing her differential allocation of rewards and punishments, goal-setting statements of various kinds, and evaluative comments.

The instrument-developing efforts of the Wisconsin, Bank Street, and Texas studies may help to extend our knowledge of teachers' patterns of behavior.

Bowers and Soar (1960) described an extended study of the human-relations skills needed by educators and the procedures that could be used in a three-week workshop to help teachers develop these skills. Working with 60 elementary-school teachers divided into control and experimental groups, they collected personality and attitude data, biographical data, and classroom observations by means of the *OScAR*. The teachers kept a log of their own activities. The question was raised of what impact the intensive workshop experience should have on teacher or pupil classroom behavior, and pertinent data were collected. In addition, analyses were made of the relationship of teacher behavior to teacher self-descriptions, the characteristics of teachers who use group activities, the correlates of effective group membership, and the relations between measures of teacher effectiveness. The significance of much of this research is its assessment of the effectiveness of laboratory training in human relations in changing the behavior of human beings, in this instance, teachers and pupils in the classroom situation.

Rippy (1960) reported a study of the relationships in the classroom between social-emotional climate, verbal emphasis, and social structure on the one hand, and, on the other, pupil skill in group planning and teacher attitudes and personality. He used Damrin's (1959) *Russell Sage Social Relations Test* and the *OScAR* of Medley and Mitzel (1958) for assessing human relations in the classroom. To assess attitudes and personality characteristics of the teachers, the *Bowers Teacher Opinion Inventory*, the *Minnesota Teacher Attitude Inventory*, the *Minnesota Multiphasic Personality Inventory*, and the *Survey of Educational Leadership Practices* were used. Fifty-four elementary-school teachers comprised the total population. Rippy's conclusions were that observing specific behaviors in the classroom afforded criteria of teacher effectiveness, that the way teachers described themselves was reflected both in the teachers' actual classroom behavior and in that of the pupils, and that teacher effectiveness is a multidimensional phenomenon.

Repeatedly in the literature of the last 30 years, brave words are encountered about the disappearance of the cleavage between cognitive and affective processes, the significance of personal-social needs and perceptions in the learning process, and trends toward reformulation of the problem of learning in a social-emotional context. Until recently these have

largely represented wishful thinking. Now there seems to be a modest ground swell of research activity within the context of the sociopsychological orientation along with a modest effort to identify the behavioral correlates of certain instructional procedures and resultants.

Conclusion

Two major trends influence researchers engaged in observation of classroom activities. One is reflected in the studies guided by the sociopsychological orientation set forth by Jensen (1960), Getzels and Thelen (1960), Gibb (1960), and Jenkins (1960). The other is seen in the attempt to define operationally the specific behaviors in which teachers and learners engage that can be hypothesized to relate significantly to group behaviors and individual learning. If these two trends merge, major advances in the control and prediction of learner and teacher activities are possible, as well as in the development of educational theory and ultimately the redirection of the teacher-education process.

Bibliography

ANDERSON, HAROLD H. "The Measurement of Domination and Socially Integrative Behavior in Teachers' Contacts with Children." *Child Development* 10: 73-89; June 1939.

ANDERSON, HAROLD H., and BREWER, HELEN M. *Studies of Teachers' Classroom Personalities: I. Dominative and Socially Integrative Behavior of Kindergarten Teachers.* Applied Psychology Monographs No. 6. Stanford, Calif.: Stanford University Press, 1945. 157 p.

ANDERSON, HAROLD H., and BREWER, JOSEPH E. *Studies of Teachers' Classroom Personalities: II. Effects of Teachers' Dominative and Integrative Contacts on Children's Classroom Behavior.* Applied Psychology Monographs No. 8. Stanford, Calif.: Stanford University Press, June 1946. 128 p. (a)

ANDERSON, HAROLD H.; BREWER, JOSEPH E.; and REED, MARY FRANCES. *Studies of Teachers' Classroom Personalities: III. Follow-Up Studies of the Effects of Dominative and Integrative Contacts on Children's Behavior.* Applied Psychology Monographs No. 11. Stanford, Calif.: Stanford University Press, December 1946. 156 p. (b)

ANDERSON, HAROLD M. "A Study of Certain Criteria of Teaching Effectiveness." *Journal of Experimental Education* 23: 41-71; September 1954.

BALES, ROBERT F. *Interaction Process Analysis.* Cambridge, Mass.: Addison-Wesley, 1950. 203 p.

BANK STREET COLLEGE OF EDUCATION. *The Classroom Processes Study.* A working paper prepared for Work Conference held by the staffs of four NIMH-related projects at the University of Wisconsin, November 10-13, 1960. New York: Bank Street College of Education (69 Bank Street), 1960. 9 p. (Mimeo.)

BOWERS, NORMAN D., and SOAR, ROBERT S. *Studies of Human Relations in the Teaching Learning Process: I. An Overview of the Project.* Nashville, Tenn.: Vanderbilt University, 1960. 11 p. (Mimeo.)

BROOKOVER, WILBUR B. "Person-Person Interaction Between Teachers and Pupils and Teaching Effectiveness." *Journal of Educational Research* 34: 272-87; December 1940.

CALVIN, ALLEN D.; HOFFMAN, FREDERICK K.; and HARDEN, EDGAR L. "The Effect of Intelligence and Social Atmosphere on Group Problem Solving Behavior." *Journal of Social Psychology* 45: 61-74; February 1957.

COGAN, MORRIS L. "Theory and Design of a Study of Teacher-Pupil Interaction." *Harvard Educational Review* 26: 315-42; Fall 1956.

COGAN, MORRIS L. "The Behavior of Teachers and the Productive Behavior of Their Pupils: I. Perception Analysis." *Journal of Experimental Education* 27: 89-105; December 1958. (a)

COGAN, MORRIS L. "The Behavior of Teachers and the Productive Behavior of Their Pupils: II. Trait Analysis." *Journal of Experimental Education* 27: 107-24; December 1958. (b)

CORNELL, FRANCIS G.; LINDVALL, CARL M.; and SAUPE, JOE L. *An Exploratory Measurement of Individualities of Schools and Classrooms.* University of Illinois Bulletin, Vol. 50, No. 75. Urbana: University of Illinois, Bureau of Educational Research, June 1953. 71 p.

DAMRIN, DORA E. "The Russell Sage Social Relations Test: A Technique for Measuring Group Problem Solving Skills in Elementary School Children." *Journal of Experimental Education* 28: 85-99; September 1959.

DAVIDSON, HELEN H., and LANG, GERHARD. "Children's Perceptions of Their Teachers' Feelings Toward Them Related to Self-Perception, School Achievement and Behavior." *Journal of Experimental Education* 29: 107-18; December 1960.

FLANDERS, NED A. "Personal-Social Anxiety as a Factor in Experimental Learning Situations." *Journal of Educational Research* 45: 100-10; October 1951.

FLANDERS, NED A. "Teacher-Pupil Contacts and Mental Hygiene." *Journal of Social Issues* 15: 30-39; No. 1, 1959.

FLANDERS, NED A. "Diagnosing and Utilizing Social Structures in Classroom Learning." *The Dynamics of Instructional Groups.* Fifty-Ninth Yearbook, Part II, National Society for the Study of Education. Chicago: University of Chicago Press, 1960. Chapter 9, p. 187-217. (a)

FLANDERS, NED A. *Interaction Analysis in the Classroom.* Minneapolis: College of Education, University of Minnesota, 1960. 35 p. (b)

GETZELS, JACOB W., and GUBA, EGAN G. "The Structure of Roles and Role Conflict in the Teaching Situation." *Journal of Educational Sociology* 29: 30-40; September 1955.

GETZELS, JACOB W., and THELEN, HERBERT A. "The Classroom Group as a Unique Social System." *The Dynamics of Instructional Groups.* Fifty-Ninth Yearbook, Part II, National Society for the Study of Education. Chicago: University of Chicago Press, 1960. Chapter 4, p. 53-82.

GIBB, JACK R. "Sociopsychological Processes of Group Instruction." *The Dynamics of Instructional Groups.* Fifty-Ninth Yearbook, Part II, National Society for the Study of Education. Chicago: University of Chicago Press, 1960. Chapter 6, p. 115-35.

GLIDEWELL, JOHN C. "The Teacher's Feelings as an Educational Resource." *Journal of Educational Research* 45: 119-26; October 1951.

GOLD, MARTIN. "Power in the Classroom." *Sociometry* 21: 50-60; March 1958.

HAIGH, GERARD V., and SCHMIDT, WARREN H. "The Learning of Subject Matter in Teacher-Centered and Group-Centered Classes." *Journal of Educational Psychology* 47: 295-301; May 1956.

HARRIS, BEN M. "The Recording Operation." A Demonstration Research Project by the staff of The University of Texas' Mental Health in Teacher Education Program. Austin: University of Texas, 1960. Unpaged. (Mimeo.)

HEDLUND, PAUL A. "Cooperative Study to Predict Effectiveness in Secondary School Teaching." *Journal of Teacher Education* 4: 230-34; September 1953.

HUGHES, MARIE M., and ASSOCIATES. *Development of the Means for the Assessment of the Quality of Teaching in Elementary Schools.* Provo: University of Utah, 1959. 406 p. (Mimeo.)

JAHODA, MARIE. *Current Concepts of Positive Mental Health.* New York: Basic Books, 1958. 136 p.

JAYNE, CLARENCE D. "A Study of the Relationship Between Teaching Procedures and Educational Outcomes." *Journal of Experimental Education* 14: 101-34; December 1945.

JENKINS, DAVID H. "Characteristics and Functions of Leadership in Instructional Groups." *The Dynamics of Instructional Groups.* Fifty-Ninth Yearbook, Part II, National Society for the Study of Education. Chicago: University of Chicago Press, 1960. Chapter 8, p. 164-84.

JENNINGS, HELEN H. "Leadership and Sociometric Choice." *Sociometry* 10: 32-49; February 1947.

JENSEN, GALE E. "Social Structure of the Classroom Group: An Observational Framework." *Journal of Educational Psychology* 46: 362-74; October 1955.

JENSEN, GALE E. "The Sociopsychological Structure of the Instructional Group." *The Dynamics of Instructional Groups.* Fifty-Ninth Yearbook, Part II, National Society for the Study of Education. Chicago: University of Chicago Press, 1960. Chapter 5, p. 83-114.

JOHNSON, MARGUERITE WILKER. "The Influence of Verbal Directions on Behavior." *Child Development* 6: 196-204; September 1935.

KOUNIN, JACOB S., and GUMP, PAUL V. "The Ripple Effect in Discipline." *Elementary School Journal* 59: 158-62; December 1958.

KOWATRAKUL, SURANG. "Some Behaviors of Elementary School Children Related to Classroom Activities and Subject Areas." *Journal of Educational Psychology* 50: 121-28; June 1959.

LEVIN, HARRY; HILTON, THOMAS L.; and LEIDERMAN, GLORIA F. "Studies of Teacher Behavior." *Journal of Experimental Education* 26: 81-91; September 1957.

LEWIS, W. W.; WITHALL, JOHN; and NEWELL, JOHN M. *A Description of Two Instructional Approaches.* Madison: Mental Health-Teacher Education Research Project, University of Wisconsin, 1960. 13 p. (Mimeo.)

LINS, LEO JOSEPH. "The Prediction of Teaching Efficiency." *Journal of Experimental Education* 15: 2-60; September 1946.

LIPPITT, RONALD. *An Analysis of Group Reaction to Three Types of Experimentally Created Social Climate.* Doctor's thesis. Iowa City: University of Iowa, 1940.

MAIER, NORMAN R. F., and MAIER, RICHARD A. "An Experimental Test of the Effects of 'Developmental' vs. 'Free' Discussion on the Quality of Group Decisions." *Journal of Applied Psychology* 41: 320-23; October 1957.

MEDLEY, DONALD M., and MITZEL, HAROLD E. "A Technique for Measuring Classroom Behavior." *Journal of Educational Psychology* 49: 86-92; April 1958.

MEDLEY, DONALD M., and MITZEL, HAROLD E. "Some Behavioral Correlates of Teacher Effectiveness." *Journal of Educational Psychology* 50: 239-46; December 1959.

MELBY, ERNEST O. "Supervision." *Review of Educational Research* 6: 324-36; June 1936.

NEWELL, JOHN M.; LEWIS, W. W.; and WITHALL, JOHN. *Mental Health-Teacher Education Research Project Research Outline.* Madison: University of Wisconsin, 1960. 67 p. (Mimeo.)

OLSON, WILLARD C., and WILKINSON, M. M. "Teacher Personality as Revealed by the Amount and Kind of Verbal Direction Used in Behavior Control." *Educational Administration and Supervision* 24: 81-93; February 1938.

PERKINS, HUGH V. "Climate Influences Group Learning." *Journal of Educational Research* 45: 115-19; October 1951.

RABINOWITZ, WILLIAM, and ROSENBAUM, IRA. "A Failure in the Prediction of Pupil-Teacher Rapport." *Journal of Educational Psychology* 49: 93-98; April 1958.

RIPPY, LEO S. *Certain Relationships Between Classroom Behavior and Attitude and Personality Characteristics of Selected Elementary Classroom Teachers.* Nashville, Tenn.: Vanderbilt University, 1960. 240 p. (Mimeo.)

RYANS, DAVID G. *Characteristics of Teachers.* Washington, D.C.: American Council on Education, 1960. 416 p.

SHAPIRO, EDNA; BIBER, BARBARA; and MINUCHIN, PATRICIA. "The Cartoon Situations Test: A Semi-Structured Technique for Assessing Aspects of Personality Pertinent to the Teaching Process." *Journal of Projective Techniques* 21: 172-84; 1957.

TROW, WILLIAM C. "Group Processes." *Encyclopedia of Educational Research.* (Edited by C. W. Harris.) New York: Macmillan Co., 1960. p. 602-12. (a)

TROW, WILLIAM C. "Role Functions of the Teacher in the Instructional Group." *The Dynamics of Instructional Groups.* Fifty-Ninth Yearbook, Part II, National Society for the Study of Education. Chicago: University of Chicago Press, 1960. Chapter 3, p. 30-50. (b)

WILLARD, RUTH A. "Discrepancies in Learning Experiences Reported in Classrooms." *Educational Administration and Supervision* 43: 339-48; October 1957.

WITHALL, JOHN. *The Development of a Technique for the Measurement of Social-Emotional Climate in Classrooms.* Doctor's thesis. Chicago: University of Chicago, 1948. 168 p.

WITHALL, JOHN. "The Development of a Technique for the Measurement of Social-Emotional Climate in Classrooms." *Journal of Experimental Education* 17: 347-61; March 1949.

WRIGHT, E. MURIEL J. "Development of an Instrument for Studying Verbal Behaviors in a Secondary School Mathematics Classroom." *Journal of Experimental Education* 28: 103-21; December 1959.

ZANDER, ALVIN, and VAN EGMOND, ELMER. "Relationship of Intelligence and Social Power to the Interpersonal Behavior of Children." *Journal of Educational Psychology* 49: 257-68; October 1958.

Additional References

BARTLETT, CLAUDE J. "Dimensions of Leadership Behavior in Classroom Discussion Groups." *Journal of Educational Psychology* 50: 280-84; December 1959.

COSGROVE, DON J. "Diagnostic Rating of Teacher Performance." *Journal of Educational Psychology* 50: 200-204; October 1959.

FINE, HAROLD J., and ZIMET, CARL N. "A Quantitative Method of Scaling Communication and Interaction Process." *Journal of Clinical Psychology* 12: 268-71; July 1956.

FLANDERS, NED A., and HAVUMAKI, SULO. "The Effect of Teacher-Pupil Contacts Involving Praise on the Sociometric Choices of Students." *Journal of Educational Psychology* 51: 65-68; April 1960.

GOWAN, JOHN C. "A Summary of the Intensive Study of Twenty Highly Selected Elementary Women Teachers." *Journal of Experimental Education* 26: 115-24; December 1957.

GRONLUND, NORMAN E. "The General Ability To Judge Sociometric Status: Elementary Student Teachers' Sociometric Perceptions of Classmates and Pupils." *Journal of Educational Psychology* 47: 147-57; March 1956.

JOHNSON, LOIS V. "A Study of Socialization in Block Play." *Journal of Educational Research* 50: 623-26; April 1957.

KEISLAR, EVAN R., and MCNEIL, JOHN D. "The Use of Pupil Accomplices to Investigate Teacher Behavior." *Journal of Experimental Education* 27: 237-40; March 1959.

LOREE, M. RAY, and KOCH, MARGARET B. "Use of Verbal Reinforcement in Developing Group Discussion Skills." *Journal of Educational Psychology* 51: 164-68; June 1960.

MCKEACHIE, WILBERT J., and SOLOMON, DANIEL. "Student Ratings of Instructors: A Validity Study." *Journal of Educational Research* 51: 379-82; January 1958.

MITZEL, HAROLD E. *A Behavioral Approach to the Assessment of Teacher Effectiveness.* New York: Office of Research and Evaluation, Division of Teacher Education of the Municipal Colleges of New York City (500 Park Avenue), 1957. 6 p.

MOUSTAKAS, CLARK E.; SIGEL, IRVING E.; and SCHALOCK, HENRY D. "An Objective Method for the Measurement and Analysis of Child-Adult Interaction." *Child Development* 27: 109-34; June 1956.

TERRELL, GLENN, JR., and SHREFFLER, JOY. "A Developmental Study of Leadership." *Journal of Educational Research* 52: 69-72; October 1958.

CHAPTER VII

Research Tools: Instrumentation in Educational Research

EDWARD B. FRY

EDUCATIONAL RESEARCH has long been dependent on the rating scale and the paper-and-pencil test. Current writings reveal that these tools are used over and over again, with a few exceptions in studies related to experimental psychology. Recently, however, attention has been drawn to new devices. Many of the new devices fall into a category commonly known as teaching machines.

Automated Learning Graph

Through the use of simple mechanical instrumentation, Keislar (1959) saw a learning curve develop. The instrument he used was a multiple-choice teaching machine, a converted "Navy Rater," which presented "pages" containing information about rectangles, followed by a multiple-choice question. The pupil responded to the question by pushing one of several buttons. If he pushed the correct button, a new "page" was presented; if he pushed a wrong button, nothing happened. An automatic recording device drew a graph. Perfect learning resulted in a vertical line, and errors made the pen move horizontally. Keislar's finding was that 14 fourth-grade and fifth-grade pupils using the instrument learned the material significantly better than the control group; however, the fact that the instrument can show exactly how the students learned at each step of the lesson and can graph the learning process automatically and instantaneously is more exciting.

With instrumentation of this type and other types described by Keislar, large amounts of data can be easily collected which will show learning plateaus, fatigue, weaknesses in presentation, effects of supplemental stimuli, and other variables.

Removal of Teacher Variable

One of the weaknesses in educational research has been the teacher variable—different teachers supplying enthusiasm or some other contaminant which makes the experiment difficult if not impossible to replicate. Instrumentation, to a large extent, can eliminate the teacher variable. For presenting lessons, instrumentation need not be complex. A tape recorder or motion picture can act as a standard instruction stimulus. A recent article on auditory abilities by a well-known reading specialist described the reading by teachers of paired words from standardized

tests. The amount of confusion which could enter with regional dialects is almost unbelievable; yet, as simple a thing as a phonograph record could give a standard stimulus. Luser, Stanton, and Doyle (1958) used recordings of 43 drill sessions in phonics to aid experimental groups. Evans, Glaser, and Homme (1960) developed a standard lesson to offer a control of that variable while other factors were varied.

Traditional Instrumentation

Educational researchers have been reluctant to adopt the established instrumentation of experimental psychology, but, with demand for more rigor, they will need and use more mechanical aids. As Grings (1954) states, ". . . specialized instrumentation . . . makes possible not only the extension of the range of senses but a reduction in the 'personal equation' of observation." He classifies instrumentation as (a) behavior recording systems (polygraph), (b) timing and counting (clock, electronic counter), (c) audition (audio oscillator), (d) vision (light meter, color plate), (e) other senses (anasthesiometer), (f) human learning and perception (memory drum, stereoscope), and (g) bioelectricity (electroencephalogram and galvanic skin response).

One ambitious doctoral candidate wired a teacher to a portable galvanic skin-response device and recorded her emotional reactions to the classroom (Goody, 1951).

An excellent and interesting review of devices and paraphernalia used in problem-solving research has been done by Ray (1955). He described multiple-choice apparatus, electromazes, water jar problems, coin weighing, the two-string problem, the cut pyramid, and problem boxes.

Discrimination

Discrimination training is common in the psychology laboratory but little used with direct relationship to education. Hively (1960) developed a teaching machine for simple discrimination which presented a stimulus picture and two choice pictures beneath glass plates; the child indicated his choice by touching a plate. Testing reading readiness of children from three to five and a half years old, he found that 15 of 27 subjects could learn simple discrimination; then, when the stimulus was gradually altered until matching was required, 4 out of 13 learned the matching task.

Hively's experiment was not a successful use of a teaching machine, but it points toward use of instrumentation in educational research. Use of the machine evolved a new contaminant, which the author described as "behavior which was shaped and maintained by accidental operation of the apparatus." Equipment manufacturers quickly saw a relationship between child-training and rat-training devices, and one company offers a mechanical dispenser for M & M's candies instead of food pellets.

Skinner's Disk Machine

Skinner (1958), a leader in the field of instrumentation for teaching and research, sought to increase the rate of learning. His disk machine presents information to be learned and asks for a response, usually in written form. The student writes a word or phrase on a tape that appears in a window. Then he activates a lever that brings the correct answer into view and, at the same time, moves his response under a glass portion of the window so that it cannot be changed. By moving the lever, the student indicates whether or not he judges his response correct; if it is incorrect, the item is presented again at the completion of the lesson.

Holland (1959) described an experiment in which 187 college sophomores used disk machines for 10 weeks in studying psychology. They worked through 1400 different frames in a median time of 14 hours. Though the experiment lacked rigorous control, 76 percent of the students said they felt the machine helped them in studying. Holland's experiment demonstrates that machines can be used in a teaching situation. Furthermore, an extremely important process, that of item analysis of student responses, was used. Heretofore, instructional materials (lectures, textbooks) have been developed almost solely by the armchair method. Machines are showing that it is possible to examine rigorously the presentation of curriculum material and find the exact point at which the student ceases to understand.

Some authors of teaching-machine programs have reported that the necessity of breaking the subject matter into the small units requiring responses revealed numerous gaps in established modes of presentation. An item analysis of machine responses positively shows these gaps. One model developed according to Skinner's principles by Rheem Caliphone Corporation includes a device which automatically tallies incorrect responses on the back of the tape. Thus the educational researcher simply needs to look at the back of the curriculum material to see where the errors occurred.

Complex Devices

One of the most elaborate devices designed for educational research is the Western Design Tutor (Western Design, 1960). It is an automatic random-access recording microfilm and motion-picture projector which contains 1000 or more motion-picture frames that can be presented in any order. By pushing a button on the control panel, the user sees a frame or a short segment of a motion-picture film. The type of instructional program usually put in this device is known as a "scrambled book"; a paragraph of material is followed by a multiple-choice question about it. The student responds to the multiple-choice question by turning to the page (in this instance, frame) numbered to correspond to the code num-

ber given by his answer choice. A scrambled book can be used without a machine, but with the scrambled book on film in the Western Design Tutor a complete record of the student's responses can be made, as well as of his latency. Since scrambled books can be written to permit the learner to be shunted through any one of several learning sequences (branching), depending on their apparent appropriateness, an automatic recording device for research is highly desirable.

Branching refers to the student's being sent, at certain points, on a remedial loop or back to an earlier point. Branching is usually involuntary on the part of the student and is determined by his errors. Other criteria, however, could be used for branching, such as latency of response or the student's conscious desire and indication that he wishes to review or speed up.

The SAKI (now known as Rheem Caliphone Corporation, DIDAK 1001) is a key-punch training device to train operators to punch cards by means of a 10-key keyboard similar to that of an adding machine. Its small circuit, similar to that of a computer, branches the rate of presentation according to the latency of the student's response.

Computers

Rath, Anderson, and Brainerd (1959) described an IBM 650 general-purpose digital computer with a typewriter input-output, which has been used for more elaborate branching based on individual differences in skill and rate. The computer also has a voluntary branching feature in which the student requests an easier program. It gives knowledge of results key by key; in other words, the student is informed of his mistake if he even types a wrong letter.

The use of computers has so interested some researchers that they have simulated computer experiments with human beings. Using a concealed human observer instead of a mass of electronic tubes, Coulson and Silberman (1960) investigated three teaching-machine variables—size of step, mode of response, and branching. Eighty junior-college students divided into eight groups were taught part of the Skinner-Holland psychology course. No significant difference was found in the mode of response, whether multiple-choice or constructed. Small-step items required more time but yielded significantly higher test scores than did large-step items on the constructed-response subtest. Branching conditions generally did not show a significant difference on the criterion test, except that they required less time when steps were skipped.

Investigating the same two response variables, multiple-choice and constructed items, Fry (1960) found that constructed-response items yielded significantly higher results than multiple-choice, when measured by a constructed-response post-test. Fry used a cardboard folder with a window slot to simulate a teaching machine. Both Coulson and Silberman

and Fry had difficulty with the multiple-choice section of the post-test, which failed to rate differences between the groups. Longer training or more complex material might have overcome this difficulty.

Continuing the same series of investigations by means of a Bendix G-15 computer, Silberman (1960) found preliminary results to indicate that effectiveness of teaching by machine is positively related to intelligence when only one trial is given of the material to be learned. Silberman's findings conflict with some of the statements from Harvard that hold that teaching-machine programs tend to obscure differences between bright and dull students.

All the devices so far discussed are for use by one student at a time. There have been several proposals for group use of computers. Ramo's (1957) conception of tomorrow's school smacks of science fiction: a computer to record a student's attendance by his thumb print, a computer to record his responses to instruction, results automatically recorded in a master memory file. The guidance counselor could at any time procure a complete record of the student's work by pushing a button.

Bushnell and Silber (1960) described Systems Development Corporation's proposed group-automated teaching device, to consist of a digital computer with magnetic-tape storage, alpha numeric printer, random-access light projector with back-projection screen, and individual desks equipped with student-response keyboards. In addition to giving knowledge of results to the student, the computer would analyze the behavior of the class to determine the selection of the material to be presented.

Language Laboratories

Language teaching by laboratory methods has been increasingly popular, in part as a result of the financial aid provided by the U.S. Office of Education and various foundations. The laboratory uses an auditory stimulus, such as a foreign language phrase, to be imitated and records the student's response on tape. The master control panel permits recording of any student's response for further analysis and research purposes. Motion pictures and slide projectors are also part of the mechanization of language teaching. The language laboratory is mainly rather an instructional than a research device; but Ramo (1957) conceived its use as an extension of psychological theory and related it to teaching machines, as did Morton (1960).

Guidance Devices

Guidance by slide projector and audio tape has proved useful in industrial situations. Irion and Briggs (1957) described the Hughes Aircraft "Video-Sonics" device, which is reported by Klass (1960) to have reduced employee errors on an electronics assembly line by 99 percent in 10

months and to have increased production from 60 percent of work standard to 90 percent. It tells the operator exactly which act to make, simultaneously showing him a picture of the act. It has implications for all manipulative training situations.

The effect of guidance, long known to be efficient in training situations, was further shown by use of the Subject-Matter Trainer, a multiple-choice machine also described by Irion and Briggs (1957), which presents an item to be matched with one of 20 answers. Primarily a research device, it can operate in a number of modes: for example, the student can be allowed to make only one error, or the student can be allowed to make any number of errors, and the machine will not proceed until the correct response is made. It proved most effective when the student read the question, pushed the button, and read the correct answer.

Simpler Teaching Devices

Not all devices are elaborate. Porter (1959) developed a write-in machine into which the pupil feeds by hand a sheet of duplicating paper. The paper is in a box so that the student cannot view it after it is fed into a roller. Activation of the roller exposes several lines at a time. The student reads the stimulus and writes an answer on the sheet. When the roller is activated, his response passes under glass, and at the same time the correct answer is shown. There are several varieties of simple write-in machines like this on the market.

Porter (1959) used his device for 22 weeks of the normal 34-week spelling program in grades 2 and 6. Standardized achievement tests showed the experimental group to be significantly superior to the control group. Porter found no relationship between intelligence scores and achievement in the experimental group, but a significant relationship in the control group. A check on the novelty factor was comparison of first-half performance scores with second-half performance scores; no difference was observed. Porter believed the experimental group spent only one-fourth as much time studying as did the control group.

Nonmachines

Use of teaching machines prompted some researchers to apply the same learning principles without mechanical aids. Homme and Glaser (1959) offered a method called a "Programmed Text," in which a stimulus item such as an incomplete statement is presented; the student responds on scratch paper, turns the page, and reads the answer. The pages have a special format of panels to save space.

Neither Eigen and Komoski (1960) nor Roe (1960) found significant differences in learning when identical material was presented by machines and programed texts.

A device which performs some of the functions of machine instruction is the tab-item, which requires the student to respond to a multiple-choice question by pulling a tab. Using this technique with 48 NROTC students, Bryan, Rigney, and Van Horn (1957) found that a student's knowing why an answer is incorrect is significantly more effective than his knowing simply that his answer is correct or incorrect.

Conclusion

Instrumentation has provided interesting vistas and pathways for the educational researcher, and also demonstrated that many of its principles can be used without the aid of mechanics. It is quite possible that, through research in instrumentation, educational researchers can significantly improve classroom instruction even if they conclude that instruments should not be used at all.

Bibliography

BRYAN, GLENN L.; RIGNEY, JOSEPH W.; and VAN HORN, CHARLES. *An Evaluation of Three Types of Information for Supplementing Knowledge of Results in a Training Technique.* Technical Report No. 19. Los Angeles: Electronics Personnel Research Group, University of Southern California, 1957. 23 p. (Mimeo.)

BUSHNELL, DON D., and SILBER, MAURICE. *The Coming of Automated Group Education.* FN 3998. Santa Monica, Calif.: System Development Corp., 1960. 12 p. (Mimeo.)

COULSON, JOHN E., and SILBERMAN, HARRY F. "Effects of Three Variables in a Teaching Machine." *Journal of Educational Psychology* 51: 135-43; June 1960.

EIGEN, LEWIS D., and KOMOSKI, P. KENNETH. "Research Summary Number 1." *Automated Teaching Project.* New York: Collegiate School, 1960. (Mimeo.)

EVANS, J. L.; GLASER, ROBERT; and HOMME, LLOYD E. "The Development and Use of a 'Standard' Program for Investigating Programmed Verbal Learning." *American Psychologist* 15: 424; July 1960.

FRY, EDWARD B. *Teaching Machines: An Investigation of Constructed Versus Multiple-Choice Response Modes.* Doctor's thesis. Los Angeles: University of Southern California, 1960. 144 p.

GOODY, GEORGE H. *An Extra-Laboratory Investigation of the Psychogalvanic Reflex and Emotional Tension.* Doctor's thesis. Los Angeles: University of Southern California, 1951. 161 p.

GRINGS, WILLIAM W. *Laboratory Instrumentation in Psychology.* Palo Alto, Calif.: National Press, 1954. 282 p.

HIVELY, WELLS. "An Exploratory Investigation of an Apparatus for Studying and Teaching Visual Discrimination, Using Pre-School Children." *Teaching Machines and Programmed Learning: A Source Book.* (Edited by A. A. Lumsdaine and Robert Glaser.) Washington, D.C.: Department of Audio-Visual Instruction, National Education Association, 1960. p. 247-56.

HOLLAND, JAMES G. "A Teaching Machine Program in Psychology." *Automatic Teaching: The State of the Art.* (Edited by Eugene Galanter.) New York: John Wiley & Sons, 1959. Chapter 5, p. 69-82.

HOMME, LLOYD E., and GLASER, ROBERT. "Relationships Between the Programmed Textbook and Teaching Machines." *Automatic Teaching: The State of the Art.* (Edited by Eugene Galanter.) New York: John Wiley & Sons, 1959. Chapter 9, p. 103-107.

IRION, ARTHUR L., and BRIGGS, LESLIE J. *Learning Task and Mode of Operation Variables in Use of the Subject-Matter Trainer.* Technical Report AFPTRC-TR-57-8. ASTIA Document No. AD 134252. Lowry Air Force Base, Colo.: Air Force Personnel and Training Research Center, 1957. 19 p.

KEISLAR, EVAN. "The Development of Understanding in Arithmetic by a Teaching Machine." *Journal of Educational Psychology* 50: 247-53; December 1959.

KLASS, PHILIP J. "Video-Sonics Cuts Production Defects." *Aviation Week* 72: 75-81; January 4, 1960.

LUSER, CAROLYN; STANTON, EILEEN; and DOYLE, CHARLES I. "Effect of an Audio-Visual Phonics Aid in the Intermediate Grades." *Journal of Educational Psychology* 49: 28-30; February 1958.

MORTON, F. RAND. *The Language Laboratory as a Teaching Machine.* Paper presented at the Language Laboratory Conference, January 1960. Bloomington: Indiana University, 1960. 85 p. (Mimeo.)

PORTER, DOUGLAS. "Some Effects of Year-Long Teaching Machine Instruction." *Automatic Teaching: The State of the Art.* (Edited by Eugene Galanter.) New York: John Wiley & Sons, 1959. Chapter 7, p. 85-90.

RAMO, SIMON. "A New Technique of Education." *Engineering and Science* 21: 17-22; October 1957.

RATH, GUSTAVE J.; ANDERSON, NANCY S.; and BRAINERD, R. C. "The IBM Research Center Teaching Machine Project." *Automatic Teaching: The State of the Art.* (Edited by Eugene Galanter.) New York: John Wiley & Sons, 1959. Chapter 11, p. 117-30.

RAY, WILBER S. "Complex Tasks for Use in Human Problem-Solving Research." *Psychological Bulletin* 52: 134-49; March 1955.

ROE, ARNOLD. *A Pilot Study—Automated Learning Research Project.* Report 60-53. Los Angeles: Department of Engineering, University of California at Los Angeles, 1960. 80 p. (Mimeo.)

SILBERMAN, HARRY F. *A Computer Controlled Teaching Machine.* Paper presented at Annual Convention of the American Psychological Association, Chicago, 1960. Santa Monica, Calif.: System Development Corp., 1960. 4 p.

SKINNER, B. F. "Teaching Machines." *Science* 128: 969-77; October 24, 1958.

WESTERN DESIGN. *Introducing the Auto Tutor.* Goleta, Calif.: Western Design, a division of U.S. Industries (Santa Barbara Airport), 1960. 35 p.

Additional References

Automation in Education, six times per year, Roger Wurtz Co. (Box 524), San Rafael, California.

BRYAN, GLENN L., and SCHUSTER, DONALD H. *An Experimental Comparison of Trouble-Shooting Training Techniques.* Technical Report No. 30. Los Angeles: Electronics Personnel Research Group, University of Southern California, 1959. 68 p. (Mimeo.)

Buyer's Guide, special supplement of *Instruments and Control Systems*, yearly, Instruments Publishing Co., Pittsburgh, Pennsylvania.

CANTOR, J. H., and BROWN, J. F. *An Evaluation of the Trainer Tester and Punchboard Tester as Electronics Trouble Shooting Aids.* Project 20-F-14-3. Report NAVTRADEVCEN 1257-2-1. Port Washington, N.Y.: U.S. Naval Training Device Center, 1956. 61 p.

CARR, WILLIAM J. *Self-Instructional Devices; Review of Current Concepts.* WADC Technical Report 59-503. Wright-Patterson Air Force Base, Ohio: Aero-Space Medical Laboratories, 1959. 23 p.

COOK, DONALD A. "On Vanishing Stimuli in Instructional Material." *Automated Teaching Bulletin* 1: 32; Summer 1960.

CRAGUN, JOHN R. *The Use of the Teaching Machine as a Study Aid at the College Level and Some Related Implications.* Master's thesis. Logan: Utah State University, 1961. 94 p.

CROWDER, NORMAN A. "Automatic Tutoring by Means of Intrinsic Programming." *Automatic Teaching: The State of the Art.* (Edited by Eugene Galanter.) New York: John Wiley & Sons, 1959. Chapter 10, p. 109-16.

DELATTRE, PIERRE. "Testing Students' Progress in the Language Laboratory." *Automated Teaching Bulletin* 1: 21-31; Summer 1960.

FALCONER, GEORGE A. *A Mechanical Device for Teaching Word Recognition to Young Deaf Children.* Doctor's thesis. Urbana: University of Illinois, 1959. 67 p.

FATTU, NICHOLAS A. *A Catalog of Trouble-Shooting Tests.* Report No. 1. Prepared for the Personnel and Training Branch, Psychological Sciences Division, Office of Naval Research. Bloomington: Institute of Educational Research, Indiana University, 1956. 130 p.

FATTU, NICHOLAS A. "Training Devices." *Encyclopedia of Educational Research.* Third edition. (Edited by Chester W. Harris.) New York: Macmillan Co., 1960. p. 1529-35.

FERSTER, CHARLES B., and SAPON, STANLEY M. "An Application of Recent Developments in Psychology to the Teaching of German." *Harvard Educational Review* 28: 58-69; Winter 1958.

FREEMAN, JAMES T. "The Effects of Reinforced Practice on Conventional Multiple Choice Tests." *Automated Teaching Machine Bulletin* 1: 19-20; September 1959.

GALANTER, EUGENE, editor. *Automatic Teaching: The State of the Art.* New York: John Wiley & Sons, 1959. 198 p.

HATCH, RICHARD S. *An Evaluation of the Effectiveness of a Self-Tutoring Approach Applied to Pilot Training.* WADC Technical Report 59-320. Wright-Patterson Air Force Base, Ohio: Aero-Medical Laboratory, Wright Air Development Center, Air Research and Development Command, July 1959. 19 p.

LORGE, SARAH. "An Evaluative Look at Foreign Language Laboratories." *Journal of Educational Sociology* 33: 229-33; January 1960.

LUMSDAINE, A. A. "Teaching Machines and Self-Instructional Materials." *Audio-Visual Communications Review* 7: 163-81; Summer 1959.

LUMSDAINE, A. A., and GLASER, ROBERT, editors. *Teaching Machines and Programmed Learning: A Source Book.* Washington, D.C.: Department of Audio-Visual Instruction, National Education Association, 1960. 724 p.

MACPHERSON, JAMES. *The Evaluation and Development of Techniques for Testing the Auditory Acuity of Trainable Mentally Retarded Children.* Doctor's thesis. Austin: University of Texas, 1960. 129 p.

MEYER, SUSAN R. "A Program in Elementary Arithmetic: Present and Future." *Automatic Teaching: The State of the Art.* (Edited by Eugene Galanter.) New York: John Wiley & Sons, 1959. Chapter 6, p. 83-84.

MUSTARD, HELEN. M., and TUDISCO, ANTHONY. "Foreign Language Laboratory in Colleges and Universities: A Partial Survey of Its Instructional Use." *Modern Language Journal* 43: 332-40; November 1959.

OMAR, FELIX, editor. "Language Teaching Today." *International Journal of American Linguistics* 26: 4; October 1960.

PORTER, DOUGLAS. "A Critical Review of a Portion of the Literature on Teaching Devices." *Harvard Educational Review* 27: 126-47; Spring 1957.

PRESSEY, SIDNEY L. "Certain Major Psycho-Educational Issues Appearing in the Conference on Teaching Machines." *Automatic Teaching: The State of the Art.* (Edited by Eugene Galanter.) New York: John Wiley & Sons, 1959. Chapter 16, p. 187-98.

Review of Scientific Instruments, monthly, American Institute of Physics, New York, New York.

SHAY, CARLETON. *The Relationship of Intelligence to Size of Item Step on a Teaching Machine Program.* Doctor's thesis. Los Angeles: University of California at Los Angeles, 1960. 82 p.

SILVERN, LEONARD C. *Implications of the Teaching Machine for Employee Development.* Speech to the Personnel Management Association, September 1960. Los Angeles: Hughes Aircraft Co. 11 p. (Mimeo.)

SMITH, EDGAR A., and QUACKENBUSH, JACK. "Devereux Teaching Aids Employed in Presenting Elementary Mathematics in a Special Education Setting." *Psychological Reports* 7: 333-36; October 1960.

STARK, EDWARD. *The Language Laboratory and Modern Language Teaching.* New York: Oxford University Press, 1960. 149 p.

STOLUROW, LAWRENCE M. "Automation in Special Education." *Exceptional Children* 27: 78-83; October 1960.

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, OFFICE OF EDUCATION. "Foreign Language Laboratories in Schools and Colleges." *American School Board Journal* 139: 25-26; November 1959.

CHAPTER VIII

Data Processing: Automation in Calculation

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AVAILABILITY of the electronic computer makes it possible currently to employ new methods in many areas of research. Performance of 1 million multiplications on a desk calculator is estimated to require about five years and to cost $25,000. On an early scientific computer, a million multiplications required eight minutes and cost (exclusive of programing and input preparation) about $10. With the recent LARC computer, 1 million multiplications require eight seconds and cost about 50 cents (Householder, 1956). Obviously it is imperative that researchers examine their methods in light of the abilities of the computer.

It should be noted that much of the information published on computers and their use has not appeared in educational or psychological literature but rather in publications specifically concerned with computers, mathematics, engineering, and business. The following selective survey is intended to guide the beginner into this broad and sometimes confusing area. It is not an exhaustive survey. It is presumed that the reader has access to the excellent Wrigley (1957) article; so the major purpose of this review is to note additions since 1957.

The following topics are discussed: equipment availability, knowledge needed to use computers, general references, programing the computer, numerical analysis, statistical techniques, operations research, and mechanization of thought processes.

Equipment Availability

As of December 1960, approximately 4000 stored-program electronic computers were in use in the United States. A wide variety of equipment is also available: desk-size engineering computers that plug into a wall outlet; many varieties of data processors with fast input, output, and access to large files of information; building-block machines whose configurations can be tailored to a variety of capacity requirements; the huge LARC of Remington Rand and IBM's STRETCH, machines that, pressing present technology to its limit, are capable of 1 million calculations per second. The use of solid-state elements, such as magnetic cores and transistors, has reduced the size and power requirements of the newer equipment and has markedly improved reliability.

Keenan (1960) presented the results of a survey of equipment, staff financing, and courses offered in connection with 100 university computing centers. The survey revealed that computers at colleges and universities

are already numerous and that soon almost any college will be able to obtain an obsolete but perfectly serviceable machine at little expense. In industry, most computers are used on a one-shift or two-shift basis, and it is not difficult to obtain machine time for research projects at nominal cost.

Although computers are available for the researcher, there is one vital shortage—trained people. Effective utilization of many computers is dependent on the ability of the researcher to use the machine himself. Thus it is important that the researcher be able to use the computer, for not only can he more easily make use of machines that are available, but he is also likely to obtain a better solution to his problem. More important, he is then equipped to use the computer to solve a larger and possibly more important problem.

Knowledge Needed To Use Computers

Several steps are necessary when a computer is used to solve a problem: (a) The problem must be defined in logical or mathematical terms. (b) This logical or mathematical formulation must be translated into an arithmetical procedure. (The translation from a mathematical statement into an arithmetical procedure is the subject matter of numerical analysis.) (c) An explicit series of instructions to the computer (the program) must be prepared to direct the computer through each step necessary to solve the problem. (d) The input data must be recorded in a form which the machine can read. (Readable media are punched cards, punched paper tape, and digital magnetic tape.) (e) Finally, the problem must be run—and the computer produces answers.

The following sections of this survey present information about these various steps. Frequently used mathematical and statistical models are presented in the sections titled "Statistical Techniques" and "Operations Research"; and a section titled "Numerical Analysis" is included. Techniques explained in the section titled "Programing the Computer" show how the researcher may use a machine without knowing all its technicalities. Punched-card input can be prepared by mark sensing or key punching, as described in the "General References" section. If many data are to be recorded from experimental equipment, it may be desirable to investigate the possibility of direct analogue-to-digital recording as discussed by Klein (1958) and Young (1960a).

General References

A number of excellent books about computers have been published recently. Andree (1958) discussed the programing of the IBM 650, and Wrubel (1959) used the IBM 650 as a vehicle to present techniques of

programing scientific problems. McCracken, Weiss, and Lee (1959) presented the programing of computers for data processing hypothetically. A comprehensive discussion of electronic data-processing machines and their use was presented in Gregory and Van Horn's (1960) book. Gille Associates (1961) compiled an equipment encyclopedia that describes various types of computers.

Sperry Rand (1959) produced *An Annotated Bibliography*. Among the periodicals of general interest not mentioned in Wrigley (1957) are *Computers and Automation*, *Control Engineering*, and *Datamation*. *Computers and Automation* periodically publishes a "Roster of Organizations in the Computer Field" and a "Who's Who in the Computer Field." Descriptive manuals are available from computer manufacturers, but most are written for reference purposes and are not easily read by the neophyte.

Programing the Computer

As in all problem solving, a precise statement of the factors and their mathematical or logical relations must first be prepared before the computer can be programed. With this statement, the researcher is ready to make the first move toward solution.

Program Library

If the solution of the problem requires use of a standard mathematical technique, the first step should always be a search for a program that may already be available to solve the problem with the computer to be used. Owing to the cost of writing computer programs, most manufacturers supply a number of basic programs and encourage the exchange of general-interest programs among their users. Many groups have organized for this exchange purpose, including SHARE (The Society To Help Avoid Repetitive Effort) for the IBM 704, 709, and 7090 computers; USE (UNIVAC Scientific Exchange) for the UNIVAC 1103A and 1105 computers; and CUE (Computer Users Exchange) for the Burroughs Datatron 220. Information regarding these organizations and their membership may be obtained from their secretaries.*

University computing centers also provide an excellent source of reference for library programs and have available some information on research in other universities. Many university computing centers distribute to other centers annual reports describing current research projects.

When deciding whether or not he can make use of a library program, the researcher must carefully examine the written description of the program to determine the following: (a) Does the program use the ap-

* The secretary for SHARE is Henry A. McCabe, Electronic Data Processing Department, Union Carbide Corporation, 270 Park Avenue, New York. The secretary for USE is J. W. Nikitas, 315 Park Avenue, South, New York. The secretary for CUE is Robert Gordon, Director of Data Processing, Stanford University, Stanford, California.

propriate mathematical method? Is the proper numerical technique used? (b) Are the characteristics of the problem at hand within the limitations imposed by the program? (For example, a program for finding the inverse of a matrix whose order does not exceed 30 cannot be used with a matrix of order 40.) (c) In what form must the information be presented to the computer? (d) Is the equipment configuration required by the program available on the machine? (e) Is the program available, along with a detailed description of its use?

When the program-library approach to the problem fails, the researcher must look to other methods. Early in the use of computers, it was realized that coding in machine language was difficult for the neophyte. In order to simplify this task, automatic programing techniques were developed which allow problems to be stated in a language which is more convenient for the researcher and which can be translated by the computer to prepare a program of machine instructions.

Interpretive Systems

Among the first approaches to automatic programing were the interpretive systems, in which the pseudo instructions of the programing language were stored in the memory of the computer, along with a program that translated these pseudo instructions into the proper sequence of machine instructions as the computer engaged in the process of solution.

The most widely known general-purpose interpretive system for the IBM 650 is "Bell Telephone Laboratories Interpretive Code," which has been described by Wolontis (1956), Andree (1958), and Wrubel (1959). Other systems were developed for special purposes, such as the University of Michigan "MITLAC" (1955), which included differential equation operations, and "SIS" (Haynam, 1957), which is designed for the solution of routine statistical problems. Frequently one of the existing interpretive systems will lend itself to the solution of the problem at hand; however, since time is required to perform the translation of each program run, this convenience must be paid for in terms of computer execution time.

Compiler Systems

A compiler is a translating program written for a particular computer which accepts a form of mathematical or logical statement as input and produces as output a machine-language program to obtain the results. Since the translation must be made only once, the time required to repeatedly run a program is less for a compiler than for an interpretive system. And since the full power of the computer can be devoted to the translating process, the compiler can use a language that closely resembles mathematics or English, whereas the interpretive languages must resemble

computer instructions. The first compiling program required about 20 man-years to create, but use of compilers is so widely accepted today that major computer manufacturers feel obligated to supply such a system with their new computers on installation.

Compilers, like the interpretive systems, reflect the needs of various types of users. For example, the IBM computers use "FORTRAN" (International Business Machines, 1957, 1958, 1959a) for scientific programing and "9 PAC" (International Business Machines, 1960c) and "Com Tran" (International Business Machines, 1960b) for commercial data processing; the Sperry Rand computers use "Math-Matic" (Sperry Rand, 1958b) for scientific programing and "Flow-Matic" (Sperry Rand, 1958a) for commercial data processing; Burroughs provides "FORTOCOM" (Turner and Waychoff, 1960) for scientific programing and "BLESSED 220" (Burroughs Corporation, 1960) for commercial data processing. There is some interest in the use of "COBOL" as a translation system common to all computers (International Business Machines, 1960a; Sperry Rand, 1960a, c; Radio Corporation of America, 1960).

Assembly Systems

Sometimes there is no recourse but to work in the computer's own language. This implies a good knowledge of the physical operations of the computer and their application to the problem at hand.

Assembly systems do not remove these requirements, but they make the task easier. They provide an easier form of expressing the operations to be performed upon the factors in memory. This is accomplished by a simple form of translating program which reads alphabetical abbreviations for the operations codes and symbolic names for memory locations and translates them into the numerical language of the computer. Usually there is a one-to-one correspondence between the steps of a symbolic program operated on by the assembler and the machine-language program it produces.

Assembly languages must conform to the design of the computer. The IBM manual for "SOAP II" (Symbolic Optimal Assembly Program written for the IBM 650 Magnetic Drum Computer) (International Business Machines, 1959b) presents an excellent example of the special nature of assembly systems. The needs for assembly systems are recognized by computer manufacturers and are considered a part of the tools supplied by them.

Numerical Analysis

Most of the groundwork for traditional numerical analysis was laid by Newton and his contemporaries in the eighteenth century. The early numerical techniques were developed by traditional mathematical methods. The advent of the modern computing machine precipitated a revolu-

tion in numerical methods, for the rapid acceptance of high-speed computers far exceeded the rate of development by traditional methods of the numerical techniques necessary. Accordingly, formal mathematical developments frequently gave way to hunches and modifications of proved methods, and much of the development in numerical analysis within the past 10 years came about as the result of modification and elaboration of traditional methods, with little concern for error analysis.

Research in numerical analysis today is chiefly concerned with rectifying its developmental shortcomings. Much of the research deals with error analysis and stability conditions of all types of numerical methods. The most complete and up-to-date information in this area is to be found in the professional journals. The major sources are *Computers and Automation*, *IRE Transactions on Electronic Computers*, *Journal of the Association of Computing Machinery*, and the *Journal of the Society for Industrial and Applied Mathematics*. Valuable articles also appear frequently in journals associated with fields in which computers are commonly used, such as physics, chemistry, astronomy, and psychology.

Today's textbooks in numerical methods concern themselves with specific areas, for example, Richtmyer's (1957) book on difference techniques in physical problems. Ralston and Wilf's (1960) text appears to be one of the few available in the general area of numerical analysis that is specifically concerned with modern computing techniques. The recent *Handbook of Automation* edited by Grabbe, Ramo, and Wooldridge (1959) provides an excellent reference for modern methods.

There has been much study of linear systems, and modern algebra saw much activity during the past three years. More than 130 computer programs involving linear algebra are available for the IBM 704, IBM 709, and IBM 7090. McKay (1957) described a special "Matrix Math Compiler" for the Remington Rand UNIVAC I. Faddeeva (1959) provided a valuable supplement to standard texts on linear algebra.

Statistical Techniques

Fortunately, computers have been in existence long enough so that many programs necessary for routine data reduction exist. A bibliography of statistical programs is beyond the scope of this review. The present purpose, therefore, is to inform the reader where such information can be obtained and to discuss the area generally.

Hamblen (1959) presented a compilation of abstracts of statistical programs for the IBM 650. He described 103 programs: 13 experimental-design, 35 correlation and multiple-regression, 6 factor-analysis, 7 curve-fitting and surface-fitting, 6 time-series and frequency-table, 10 nonparametric-statistics, and 26 random-numbers and miscellaneous. These are only a few, relatively, of the statistical programs available for one computer.

Michael (1959, 1960) edited a section of *Educational and Psychological Measurement* devoted to programing and procedures. In it Iker reported on computation by IBM 650 of group differences and means (1960a) and of item analysis using either a continuous (1960b) or a dichotomous criterion variable (1960c). Gaddis (1959) discussed questionnaire analysis. Kamman and others (1959) described a follow-up of work on test scoring by means of accounting machines. Madden (1959) used an IBM 709 for efficient test-battery analysis. Multivariate and a variety of factor-analysis applications were presented by Kaiser (1959, 1960) and by Horst, Dvorak, and Wright (1960).

The Statistical Laboratory of Case Institute of Technology began in the fall of 1960 to compile a "Bibliography of Statistical Computer Routines," which when completed should provide a useful tool for the researcher. Information on computer programs in this area frequently appears in professional journals such as *Psychometrika, Educational and Psychological Measurements, Journal of Experimental Psychology, Journal of the American Statistical Association,* and *Behavioral Science.*

Operations Research

Operations research is the application of the scientific method to management problems in organizations. Many ideas and techniques developed in the operations research literature may have value for educational researchers. An excellent bibliography of the field of operations research was prepared by the Case Institute of Technology Operations Research Group (1958). Among recent books on the subject are those by Churchman, Ackoff, and Arnoff (1957), Saaty (1959), and Sasieni, Yaspan, and Friedman (1959). Periodicals devoted to this subject include *Operations Research* and *Management Science.*

Linear programing is a mathematical technique for maximization or minimization of a linear function subject to a number of linear restrictions. Riley and Gass (1958) prepared a bibliography of linear programing. Among the many good books on the subject are those by Stockton (1960), Gass (1958), Ferguson and Sargent (1958), and Dorfman, Samuelson, and Solow (1958). Stockton's presentation is elementary and serviceable to those without mathematical background. Orchard-Hays (1958) described several computer programs for solving linear programing problems, and Shetty (1959) discussed the effect of changes or inaccuracies in the coefficients in a linear programing problem.

The theory of games concerns itself with conflict situations. Luce and Raiffa (1957) presented an excellent over-all survey of game theory and its significance in the social and behavioral sciences. Flood (1958) provided a game-theoretic discussion of several common conflict situations. Ellsberg (1956) gave an interesting critique of game theory.

Queuing (or waiting line) theory is concerned with problems in which

services are provided to *customers* who arrive in a random manner and wait in line to receive the service. The objective of the theory is to minimize the total of the cost of providing the service and the cost of customer waiting. Morse (1958) devoted a book to queuing theory and its applications, and Shelton (1960) presented a compilation of several formulas that have been developed for various types of queuing situations.

One of the most useful tools for the analysis of large and complex problems is simulation, by means of which a model of the situation under investigation is operated (usually by a computer) through succeeding intervals of time in order to evaluate performance under assumed conditions. Malcolm (1958) presented a number of examples of simulation and its use, and Martin (1959a) described several large simulation studies. A bibliography of simulation and its use was presented by Malcolm (1960). The industrial dynamics variety of simulation was discussed by Forrester (1958, 1959), and a simulation of the shoe industry was described by Cohen (1960). Enke (1958) described a large simulation in which human decision makers were integrated into a computer simulation in a situation too complicated to be handled by either the persons or the computer alone. Conway, Johnson, and Maxwell (1958) and the IBM's *Job Shop Simulation Application* (1960d) described general-purpose computer programs for simulation of job-shop dispatching operations. Davis (1959) discussed an automatic programing system designed for writing simulation programs.

A variation of the simulation technique called decision gaming (or management gaming, management decision simulation) was widely used for training and for research into various aspects of decision making. Several of these simulation exercises and their use were discussed by Bellman (1958), Martin (1959b), IBM's *Management Decision-Making Laboratory* (undated), and Sperry Rand's *Marketing Management Simulation* (1960b). The University of Kansas (1959) published the proceedings of a symposium devoted to discussion of various exercises of the same kind and the points of view of several people concerning their use. Guetzkow (1959) described experiments with the use of noncomputer simulation exercises in the area of international relations.

Mechanization of Thought Processes

A great deal of research effort is currently devoted to the possibility of the use of computers or the design of more advanced machines to perform in a manner that resembles the functioning of the human brain in certain respects. Much of this research has used the digital computer as an indispensable research tool. A National Physical Laboratory (1959) publication included a number of papers on this subject, and *Behavioral Science* reported a good deal of research. Young (1960a, b) and Uhr (1959) presented general surveys of the work in this field.

One basic approach is that of devising and (through computer simulation) testing theories of how the neurons of the brain interact with one another in thought processes. Reiss (1960) provided an excellent introduction to this approach. Another tack, the simulation of human methodological approaches to problem-solving activity, was taken by Gelernter and Rochester (1958); Newell, Shaw, and Simon (1958, 1959); Friedberg (1958); Simon and Newell (1958); and Hagensick (1960). Green (1960) reported on an automatic programing language devised to simplify research in this area.

The important problem of machine retrieval of information from (sometimes specialized) libraries has received much attention over the last few years. Vandenberg (1960) and Ledley and Lusted (1960) reported on the status of the use of computers for medical information retrieval and diagnosis. Similar projects in chemistry, law, and other fields were briefly reported in *Computers and Automation* (1960a). Discussions of some of the concepts involved in information retrieval may be found in Bourne and Engelbart (1958) and Luhn (1957).

Machine translation of languages was discussed by Blickstein (1960) and MacDonald (1960), and the outline of a recent conference was reported by *Computers and Automation* (1960b) in "National Symposium on Machine Translation." Coulson and Silberman (1960) described the use of a computer as a component of a sophisticated teaching machine.

Summary

This review has surveyed research on computers since Wrigley's 1957 article. During this period the number of computers in existence has increased to an extent that makes them available for research. Programing techniques have significantly advanced, and mechanisms have been established for the interchange of programs of general interest. Courses in programing for beginners are available to faculty members at most institutions that have computing centers.

Significant progress has been made in the use of computers in processing data, in computation, and in the non-numerical areas of simulation of intelligent behavior. It is certain that use of computers in educational research will increase greatly throughout the next several years.

Bibliography

ANDREE, RICHARD V. *Programming the IBM 650 Magnetic Drum Computer and Data-Processing Machine.* New York: Henry Holt & Co., 1958. 109 p.

BELLMAN, R. "Top Management Decision and Simulation Processes." *Journal of Industrial Engineering* 9: 459-64; September-October 1958.

BLICKSTEIN, B. D. "Machine Translation and General Purpose Computers." *Computers and Automation* 9: 20-22; April 1960.

BOURNE, CHARLES P., and ENGELBART, DOUGLAS C. "Facets of the Technical Information Problem." *Datamation* 4: 6-12; September-October 1958.

BURROUGHS CORPORATION. *BLESSED 220 System Manual.* Pasadena, Calif.: Electro-Data Division, Burroughs Corporation, 1960.

CASE INSTITUTE OF TECHNOLOGY OPERATIONS RESEARCH GROUP. *A Comprehensive Bibliography on Operations Research.* New York: John Wiley & Sons, 1958. 188 p.

CHURCHMAN, C. WEST; ACKOFF, RUSSELL L.; and ARNOFF, E. LEONARD. *Introduction to Operations Research.* New York: John Wiley & Sons, 1957. 645 p.

COHEN, KALMAN J. *Computer Models of the Shoe, Leather, Hide Sequence.* Englewood Cliffs, N.J.: Prentice-Hall, 1960. 156 p.

COMPUTERS AND AUTOMATION. "The Armed Services Technical Information Agency Becomes Automated to Solve Retrieval Problems." *Computers and Automation* 9: 1B; 1960. (a)

COMPUTERS AND AUTOMATION. "National Symposium on Machine Translation." *Computers and Automation* 9: 9-12; February 1960. (b)

CONWAY, R. W.; JOHNSON, B. M.; and MAXWELL, W. L. *The Cornell Research Simulator.* Ithaca, N.Y.: Department of Industrial and Engineering Administration, Cornell University, 1958. 120 p.

COULSON, JOHN E., and SILBERMAN, HARRY F. "Teaching Machine Simulated by Computer." *Computers and Automation* 9: 9-10; October 1960.

DAVIS, LAURENCE A. *MCSIP—A Monte Carlo Simulation Interpretive Program for the IBM 650 MDDPM Computer.* Master's thesis. Pittsburgh: Computation and Data Processing Center, University of Pittsburgh, 1959. 210 p. (Mimeo.)

DORFMAN, ROBERT; SAMUELSON, PAUL A.; and SOLOW, ROBERT M. *Linear Programming and Economic Analysis.* New York: McGraw-Hill Book Co., 1958. 527 p.

ELLSBERG, DANIEL. "Theory of the Reluctant Duelist." *American Economic Review* 46: 909-23; December 1956.

ENKE, STEPHEN. "On the Economic Management of Large Organizations: A Laboratory Study." *Journal of Business of the University of Chicago* 31: 280-92; October 1958.

FADDEEVA, V. N. *Computational Methods of Linear Algebra.* Translated by Curtis D. Benster. New York: Dover Publications, 1959. 252 p.

FERGUSON, ROBERT O., and SARGENT, LAUREN F. *Linear Programming: Fundamentals and Applications.* New York: McGraw-Hill Book Co., 1958. 375 p.

FLOOD, MERRILL M. "Some Experimental Games." *Management Science* 5: 5-26; October 1958.

FORRESTER, JAY W. "Industrial Dynamics—a Major Break-Through for Decision Makers." *Harvard Business Review* 36: 37-66; July-August 1958.

FORRESTER, JAY W. "Advertising: A Problem in Industrial Dynamics." *Harvard Business Review* 37: 100-110; March-April 1959.

FRIEDBERG, R. M. "A Learning Machine—Part 1." *I.B.M. Journal of Research and Development* 2: 2-13; January 1958.

GADDIS, L. WESLEY. "Questionnaire Analysis Program." *Educational and Psychological Measurement* 19: 435-37; Autumn 1959.

GASS, SAUL I. *Linear Programming: Methods and Applications.* New York: McGraw-Hill Book Co., 1958. 223 p.

GELERNTER, H. L., and ROCHESTER, N. "Intelligent Behavior in Problem-Solving Machines." *I.B.M. Journal of Research and Development* 2: 336-45; October 1958.

GILLE ASSOCIATES. *Data Processing Equipment Encyclopedia: Section 1: Punched Card, Punched Tape: Section 2: Computers, Electronics.* Detroit: Gille Associates (22nd floor, Book Tower), 1961. Section 1, 450 p. Section 2, 450 p.

GRABBE, EUGENE M.; RAMO, SIMON; and WOOLDRIDGE, DEAN E., editors. *Handbook of Automation, Computation, and Control. Vol. 2, Computers and Data Processing.* New York: John Wiley & Sons, 1959. 1070 p.

GREEN, BERT F., JR. "IPL-V: The Newell-Shaw-Simon Programming Language." *Behavioral Science* 5: 94-98; January 1960.

GREGORY, ROBERT HENRY, and VAN HORN, RICHARD L. *Automatic Data-Processing Systems: Principles and Procedures.* San Francisco: Wadsworth Publishing Co., 1960. 705 p.

GUETZKOW, HAROLD. "A Use of Simulation in the Study of Inter-Nation Relations." *Behavioral Science* 4: 183-91; July 1959.

HAGENSICK, PAUL W. "Logic by Machine: Programming the LGP-30 to Solve Problems in Symbolic Logic." *Behavioral Science* 5: 87-94; January 1960.

HAMBLEN, JOHN W. *Statistical Programs for the IBM 650.* Paper presented to the joint meeting of the Institute of Mathematical Statistics and the Association for Computing Machinery at the Case Institute of Technology. Cleveland: Case Institute of Technology, April 1959.

HAYNAM, G. E. *A Statistical Interpretive System for the IBM 650 Magnetic Drum Calculator.* Cleveland: Case Institute of Technology, 1957. 27 p.

HORST, PAUL; DVORAK, AUGUST; and WRIGHT, CALVIN. *Computer Applications to Psychological Problems.* Seattle: University of Washington, 1960. 26 p. (Mimeo.)

HOUSEHOLDER, ALTON S. "Solving Problems with Digital Computers." *Computers and Automation* 5: 6-9; 1956.

IKER, HOWARD P. "Group Differences and Group Means with the Augmented IBM 650." *Educational and Psychological Measurement* 20: 171-79; Spring 1960. (a)

IKER, HOWARD P. "Item Analysis on the Augumented IBM 650 Using a Continuous Criterion Variable." *Educational and Psychological Measurement* 20: 153-62; Spring 1960. (b)

IKER, HOWARD P. "Item Analysis on the Augmented IBM 650 Using a Dichotomous Criterion Variable." *Educational and Psychological Measurement* 20: 163-70; Spring 1960. (c)

INTERNATIONAL BUSINESS MACHINES. *FORTRAN Automatic Coding System for the 704 Data Processing System.* Form C-28-6003-0. New York: International Business Machines (590 Madison Avenue), 1957. 60 p.

INTERNATIONAL BUSINESS MACHINES. *FORTRAN Automatic Coding System for the 709 Data Processing System.* Form C-28-6054-0. New York: International Business Machines (590 Madison Avenue), 1958.

INTERNATIONAL BUSINESS MACHINES. *FORTRANSIT Coding System for the IBM 650 Data Processing System.* Form C-28-4028. New York: International Business Machines (590 Madison Avenue), 1959. 80 p. (a)

INTERNATIONAL BUSINESS MACHINES. *SOAP II for the IBM Data Processing Systems.* Form C-28-4000. New York: International Business Machines (590 Madison Avenue), 1959. 100 p. (b)

INTERNATIONAL BUSINESS MACHINES. *The COBOL Translator.* Form F28-8053. New York: International Business Machines (590 Madison Avenue), 1960. 54 p. (a)

INTERNATIONAL BUSINESS MACHINES. *General Information Manual IBM Commercial Translator.* Form F28-8043. International Business Machines (590 Madison Avenue), 1960. 118 p. (b)

INTERNATIONAL BUSINESS MACHINES. *9 PAC Users' Reference Manual—709 Reports Generator, 709 File Processor, 9 PAC Sort.* New York: International Business Machines SHARE Distribution Agency (590 Madison Avenue), 1960. (c)

INTERNATIONAL BUSINESS MACHINES. *Job Shop Simulation Applications.* M. and A.-1. New York: Math and Applications Department, International Business Machines (590 Madison Avenue), 1960. 114 p. (Mimeo.) (d)

INTERNATIONAL BUSINESS MACHINES. *Management Decision-Making Laboratory—Instructions for Participants.* New York: International Business Machines (590 Madison Avenue), undated.

KAISER, HENRY F. "Computer Program for Varimax Rotation in Factor Analysis." *Educational and Psychological Measurement* 19: 413-20; Autumn 1959.

KAISER, HENRY F. "The Application of Electronic Computers to Factor Analysis." *Educational and Psychological Measurement* 20: 141-51; Spring 1960.

KAMMAN, JAMES F., and OTHERS. "Scoring Psychological Tests on Accounting Machines: A Follow-Up Report." *Educational and Psychological Measurement* 3: 421-23; Autumn 1959.

KEENAN, T. A. *Fourth Annual Survey of University Computing Centers.* Report No. 8. Rochester, N.Y.: University of Rochester, July 1960. 109 unpaged leaves.

KLEIN, MARTIN J. "Analog-Digital Converters: An Evaluation." *Datamation* 4: 5-9; May-June 1958.

LEDLEY, ROBERT S., and LUSTED, LEE B. "Computers in Medical Data Processing." *Operations Research* 8: 299-310; May-June 1960.

LUCE, R. DUNCAN, and RAIFFA, HOWARD. *Games and Decisions: Introduction and Critical Survey; A Study of the Behavioral Models Project, Bureau of Applied Social Research, Columbia University.* New York: John Wiley & Sons, 1957. 509 p.

LUHN, H. P. "A Statistical Approach to Mechanized Encoding and Searching of Literary Information." *I.B.M. Journal of Research and Development* 1: 309-17; October 1957.

MCCRACKEN, DANIEL D.; WEISS, HAROLD; and LEE, TSAI-HWA. *Programming Business Computers.* New York: John Wiley & Sons, 1959. 510 p.

MACDONALD, NEIL. "The Photoscopic Language Translator." *Computers and Automation* 9: 6-8; August 1960.

MCKAY, WILLIAM. *The Matrix Math Compiler for UNIVAC I.* Philadelphia: the Franklin Institute, 1957. 84 p.

MADDEN, DALE E., and OTHERS. "IBM 709 FORTRAN Program for Test Battery Analysis." *Educational and Psychological Measurement* 19: 439-44; Autumn 1959.

MALCOLM, D. G. "Bibliography on the Use of Simulation in Management Analysis." *Operations Research* 8: 169-77; March-April 1960.

MALCOLM, D. G., editor. *Report of System Simulation Symposium.* New York: American Association of Industrial Engineers (32 West Fortieth Street), 1958. 106 p.

MARTIN, E. W., JR. "Simulation in Organizational Research." *Business Horizons* 2: 68-77; Fall 1959. (a)

MARTIN, E. W., JR. "Teaching Executives via Simulation." *Business Horizons* 2: 100-109; Summer 1959. (b)

MICHAEL, WILLIAM B., editor. "Electronic Computer Programs and Accounting Machine Procedures." *Educational and Psychological Measurement* 19: 413-44; Autumn 1959.

MICHAEL, WILLIAM B., editor. "Electronic Computer Programs and Accounting Machine Procedures." *Educational and Psychological Measurement* 20: 143-91; Spring 1960. ——20: 569-613; Autumn 1960.

MORSE, PHILIP M. *Queues, Inventories and Maintenance.* Operations Research Society of America, Publications in Operations Research No. 1. New York: John Wiley & Sons, 1958. 202 p.

NATIONAL PHYSICAL LABORATORY. *Mechanisation of Thought Processes.* London: Her Majesty's Stationery Office, 1959. 2 vol., 980 p.

NEWELL, ALLEN; SHAW, J. C.; and SIMON, HERBERT A. "Elements of a Theory of Human Problem Solving." *Psychological Review* 65: 151-66; May 1958.

NEWELL, ALLEN; SHAW, J. C.; and SIMON, HERBERT A. *The Processes of Creative Thinking.* Paper P-1320. Santa Monica, Calif.: RAND Corporation, January 1959. 82 p.

ORCHARD-HAYS, WILLIAM. "Evolution of Linear Programming Computing Techniques." *Management Science* 4: 183-90; January 1958.

RADIO CORPORATION OF AMERICA. *The 501 COBOL Narrator.* New York: Electronic Data Processing Division, Radio Corporation of America (30 Rockefeller Plaza), November 1960. 143 p.

RALSTON, ANTHONY, and WILF, M. S., editors. *Mathematical Methods for Digital Computers.* New York: John Wiley & Sons, 1960. 293 p.

REISS, RICHARD F. "The Digital Simulation of Neuro-Muscular Organisms." *Behavioral Science* 5: 343-58; October 1960.

RICHTMYER, ROBERT D. *Difference Methods for Initial-Value Problems.* Interscience Tracts in Pure and Applied Science No. 4. New York: Interscience Publishers, 1957. 238 p.

RILEY, VERA, and GASS, SAUL T. *Linear Programming and Associated Techniques, a Comprehensive Bibliography on Linear, Non-linear, and Dynamic Programming.* Revised edition. Bibliographic Reference Series No. 5. Programming for Policy Decision Vol. 1. Baltimore: Johns Hopkins Press, 1958. 613 p.

SAATY, THOMAS L. *Mathematical Methods of Operations Research.* New York: McGraw-Hill Book Co., 1959. 421 p.

SASIENI, MAURICE; YASPAN, ARTHUR; and FRIEDMAN, LAWRENCE. *Operations Research: Methods and Problems.* New York: John Wiley & Sons, 1959. 316 p.

SHELTON, J. R. "Solution Methods for Waiting Line Problems." *Journal of Industrial Engineering* 11: 293-303; July-August 1960.

SHETTY, C. M. "Sensitivity Analysis in Linear Programming." *Journal of Industrial Engineering* 10: 379-86; September-October 1959.

SIMON, HERBERT A., and NEWELL, ALLEN. "Heuristic Problem Solving: The Next Advance in Operations Research." *Operations Research* 6: 1-10; January-February 1958.

SPERRY RAND CORPORATION. *Flow-Matic Programming System.* Form No. U 1518. New York: Remington Rand UNIVAC Division, Sperry Rand Corporation (315 Park Avenue, S.), 1958. 115 p. (a)

SPERRY RAND CORPORATION. *UNIVAC Math-Matic Programming System.* Form No. U 1568. New York: Remington Rand UNIVAC Division, Sperry Rand Corporation (315 Park Avenue, S.), 1958. 87 p. (b)

SPERRY RAND CORPORATION. *An Annotated Bibliography.* UNIVAC Educational Series, No. 3. New York: Remington Rand UNIVAC Division, Sperry Rand Corporation (315 Park Avenue, S.), 1959. 54 p.

SPERRY RAND CORPORATION. *B-2/80 Supplement to Preliminary Users' Reference Manual To Accompany the COBOL Manual.* New York: Remington Rand UNIVAC Division, Sperry Rand Corporation (315 Park Avenue, S.), November 1960. 35 p. (a)

SPERRY RAND CORPORATION. *Marketing Management Simulation.* New York: Remington Rand UNIVAC Division, Sperry Rand Corporation (315 Park Avenue, S.), 1960. 8 p. (b)

SPERRY RAND CORPORATION. *Preliminary Users' Reference Manual To Accompany the COBOL Manual, B-2 Compiler.* New York: Remington Rand UNIVAC Division, Sperry Rand Corporation (315 Park Avenue, S.), April 1960. 149 p. (c)

STOCKTON, R. S. *Introduction to Linear Programming.* Boston: Allyn & Bacon, 1960. 104 p.

TURNER, L. D., and WAYCHOFF, R. E. *FORTOCOM and Algebraic Compiler for the Burroughs 205.* Pasadena, Calif.: Electro-Data Division, Burroughs Corporation, 1960.

UHR, LEONARD. "Latest Methods for the Conception and Education of Intelligent Machines." *Behavioral Science* 4: 248-51; July 1959.

UNIVERSITY OF KANSAS. *Proceedings of the National Symposium on Management Games.* Lawrence: Center for Research in Business, University of Kansas, 1959. 104 p.

UNIVERSITY OF MICHIGAN. *Programming Manual for MITLAC 650 Routine.* Ann Arbor: Statistical Research Laboratory, University of Michigan, 1955.

VANDENBERG, STEVEN G. "Medical Diagnosis by Computer: Recent Efforts, and Outlook." *Computers and Automation* 9: 12-14; February 1960.

WOLONTIS, V. M. "Bell Telephone Laboratory Interpretive System." *IBM Technical Newsletter No. 11.* Form 34-68822-0. New York: International Business Machines (590 Madison Avenue), 1956. 63 p.

WRIGLEY, CHARLES. "Data Processing: Automation in Calculation." *Review of Educational Research* 27: 528-43; December 1957.

WRUBEL, MARSHAL H. *A Primer of Programming for Digital Computers.* New York: McGraw-Hill Book Co., 1959. 230 p.

YOUNG, L. H. "Computers Unfold the Secrets of Human Behavior." *Control Engineering* 7: 120-24; October 1960. (a)

YOUNG, L. H. "Duplicating the Performance of Biological Systems." *Control Engineering* 7: 28-31; October 1960. (b)

Periodical Sources for Related Materials

Behavioral Science, quarterly, University of Michigan Mental Health Research Institute, Ann Arbor, Michigan.

Computers and Automation, monthly, Berkeley Enterprises (160 Warren Street), Roxbury, Massachusetts.

Control Engineering, monthly, McGraw-Hill Publishing Co., New York, New York.

Datamation, bimonthly, F. D. Thompson Publications, Chicago, Illinois.

Educational and Psychological Measurement, quarterly, G. Frederic Kuder (Box 6907, College Station), Durham, North Carolina.

IRE Transactions on Electronic Computers, quarterly, Institute of Radio Engineers for the Professional Group on Electronic Computers, New York, New York.

Journal of Experimental Psychology, monthly, American Psychological Association (1333 Sixteenth Street, N.W.), Washington, D.C.

Journal of the American Statistical Association, quarterly, American Statistical Association (Curtis Reed Plaza), Menasha, Wisconsin.

Journal of the Association of Computing Machinery, quarterly, Association for Computing Machinery (Mount Royal and Guilford Avenue), Baltimore, Maryland.

Journal of the Society for Industrial and Applied Mathematics, quarterly, Society for Industrial and Applied Mathematics, Philadelphia, Pennsylvania.

Management Science, quarterly, Institute of Management Sciences (Mount Royal and Guilford Avenues), Baltimore, Maryland.
Operations Research, bimonthly, Operations Research Society of America (Mount Royal and Guilford Avenues), Baltimore, Maryland.
Psychometrika, quarterly, Psychometric Society (1407 Sherwood Avenue), Richmond, Virginia.

Index to Volume XXX

Page citations are made to single pages; these are often the beginning of a chapter, section, or running discussion dealing with the topic.

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